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DISCLAIMER

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Evidence for the Synthesis of $^{267}110$ Produced by the ^{59}Co+^{209}Bi Reaction

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An experiment to synthesize element 110 by the ^{59}Co+^{209}Bi reaction has been performed at the SuperHILAC at the Lawrence Berkeley Laboratory. One event with many of the expected characteristics of a successful synthesis of $^{267}110$ was observed. This event corresponds to a production cross section of about one picobarn.

1. INTRODUCTION

In August-September, 1991, we performed an experiment to attempt the synthesis of element 110 via the ^{59}Co+^{209}Bi reaction. The basic idea of this experiment was to bombard ^{209}Bi with ^{59}Co ions at an energy near the barrier and look for the production of a very-short-lived α-emitter (decaying by the emission of an 11-12 MeV α-particle) that was connected genetically to known lower Z nuclei. In this contribution we describe the essential features of that experiment and present our evidence for the possible observation of one atom of element 110.

2. EXPERIMENTAL

The experiment was performed at the LBL SuperHILAC accelerator. The synthesis used was the "cold fusion" reaction, ^{209}Bi(^{59}Co,n)$^{267}110$, chosen because of the ready availability of the projectile and target nuclei. Because the cross section for this reaction was expected to be of the order of picobarns, a new gas-filled magnetic separator/detector system, SASSY2 [1], was specially constructed for this experiment (Figure 1). It was

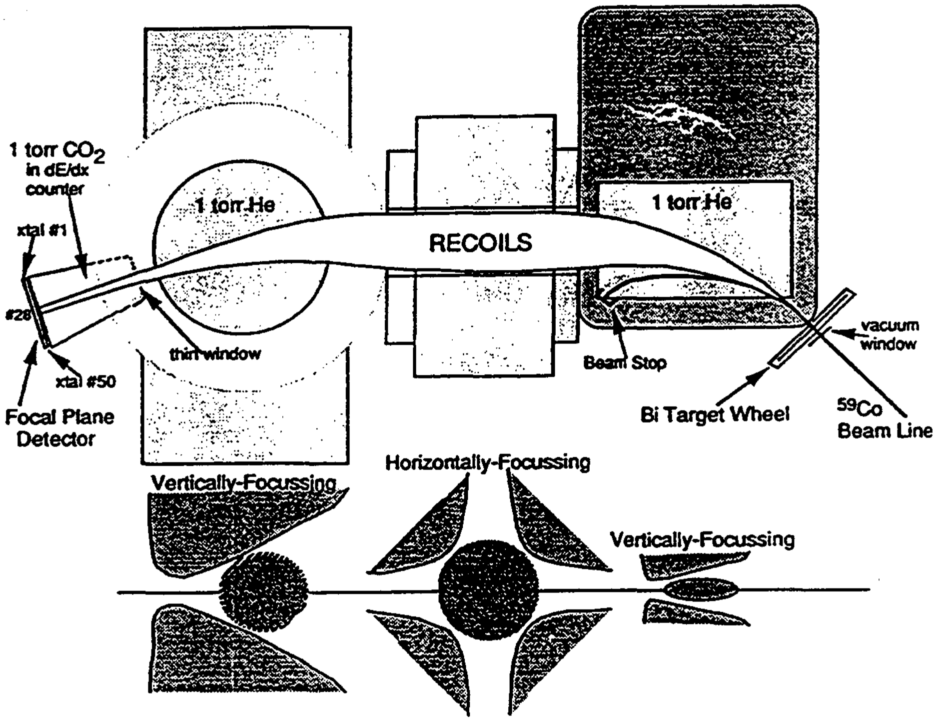

Figure 1. Schematic diagram of the SASSY2 separator.

essentially 100% efficient and offered superior rejection of background events involving scattered beam nuclei and target-like transfer products. This device was a rebuilt version of the previously-described [2] separator SASSY. SASSY2 differed from its predecessor in that: (a) it had a recoil flight path of 2.5 m, rather than 4 m, to decrease recoil scattering and increase recoil transport efficiency, (b) it had a total bending angle of 55°, rather than 22°, to increase discrimination against beam particles and target-like fragments, (c) it had Hall probes for the direct measurement of the magnetic fields, (d) it had a 30-cm long CO_2-filled proportional counter for a dE/dx measurement just before the focal plane, and (e) it had a larger area, position-sensitive 50-detector focal plane array sensitive to alpha particle energies > 0.5 MeV. The separator operated at a helium pressure of 1 torr and the CO_2 in the dE/dx proportional counter was at the same pressure.

The beam entered the separator through a thin window (50-250 $\mu g/cm^2$ of C or C-Al-C). The beam then struck the 0.5 mg/cm^2 Bi metal targets (supported on 150-300 $\mu g/cm^2$ Al substrates) which were mounted on a rapidly rotating target wheel to dissipate the energy deposited by the beam. Because of the occasional failure of windows the beam current was limited to < 0.25 pμa for much of the experiment. The intensity of the ^{59}Co beam was monitored during the runs by using the separator itself as a Faraday cup. This method was checked twice by calorimeter measurements. The integrated beam fluence was 1.49×10^{18} ions delivered over a period of 41 days.

The energy of the ^{59}Co beam was measured as it entered the SASSY2 separator in three ways: (1) by using the accelerator phase probes, (2) by measuring the magnetic field of the steering magnet in the beam line leading to the separator, and (3) by the use of silicon detectors. The pulse-height defect for these silicon detectors for ≈ 300-MeV ^{59}Co ions was measured in a subsequent experiment at the LBL 88-Inch Cyclotron. The losses of energy in passing through the thin entrance window, the target backing, and half the target thickness were calculated using standard range-energy relationships [3]. These losses were typically 3.2, 3.3, and 2.7 MeV, respectively. To clarify an ambiguous measurement of the energy used in the particular run where we observed the interesting event, we used the stratagem of determining the energy used in that run relative to the others by examining the yields of target-like transfer products made in the bombardments. These relative yields are sensitive indicators of relative bombarding energies and this measurement showed that the energy used in this particular experiment was about 5.1 MeV/A.

In an earlier test run the transmission of the SASSY2 spectrometer was measured to be 76 ± 8% for the Ac evaporation residues produced in the reaction of 232-MeV ^{51}V with ^{nat}Dy. Following this measurement, a source of ^{249}Cf alpha particles was used to adjust the spectrometer to improve its transmission and the realigned spectrometer was then found to have an angular acceptance of ±50 mrad in both the horizontal and vertical directions. This measurement implies a transmission of 96–98% for the evaporation residues in this experiment.

The focal plane detector consisted of 50 Si detectors, each 3-mm wide and 28-mm high in 5 groups of ten on separate Si wafers, each wafer being position-sensitive in the vertical direction. The efficiency for detecting a full-energy implanted alpha-particle signal was calculated to be 57% in any one detector; the overall average efficiency for detecting any alpha particle with $E > 0.5$ MeV was assumed to be 94% on the basis of the active area of the crystals. The detectors had been used previously for a long period of time with a consequent degradation in resolution in energy and position, the former to about 100 keV and the latter to 2 mm, both expressed as FWHM.

3. RESULTS

One unique event in the entire 41-day interval, the element-110 candidate, was observed with multiple correlated signals at a projectile energy close to 5.1 MeV/A. In this event, a recoil passed through the dE/dx chamber, giving a signal consistent with that expected for element 110. This recoil stopped in detector #28, depositing an observed energy of 34 MeV at a position that was horizontally close to the middle of the focal plane at the expected magnetic rigidity for element-110 recoils. This energy is in reasonable agreement with what one expects, since the initial calculated recoil energy was 66 MeV in the middle of the target, 15 MeV was the loss in traversing the separator, and 11 MeV was the loss that was measured for the pulse-height detector defect in a later experiment.

Four microseconds after implantation, an 11.6-MeV alpha particle was detected in detector #28, followed 6.0 s later by a 2.2-MeV alpha particle. (A correction of 8 percent was applied to the recorded pulse height in deriving the 11.6 MeV energy for the first alpha particle. This correction was for the effects of pileup and was duplicated in post-run tests of the electronics.) An 8.31-MeV alpha particle was then detected 19.7 s after the recoil in this detector at a position that was 2.0 mm from the implantation site. Both the 2.2- and 8.3-MeV alpha particles were detected during the beam-on time (30% duty cycle: 8.3 ms on, 19.4 ms off). No further events in this energy region were observed in this detector for the next 900 seconds.

To understand our result, one needs to take into account the predicted decay properties of the relevant nuclides made in the chosen reaction. The nuclide $^{267}110$ is predicted to decay primarily by alpha particle emission with Q_α=11.7 MeV [6] and a half life of 18 μs[7]. The daughter of $^{267}110$ is the unknown isotope ^{263}Hs (element 108, hassium) and is predicted to have $Q_\alpha = 11.0$ MeV with a $t_{1/2} = 170 \mu s$. The granddaughter of $^{267}110$ is ^{259}Sg (element 106, seaborgium), known to decay by alpha emission $\{E_\alpha = 9.62(78\%)$, 9.36(11%), and 9.03(11%) MeV$\}$ with $t_{1/2} \approx 0.5$ s. It is probable that ^{259}Sg also decays, in part, by electron capture (EC) forming ^{259}Ha since significant(10-35%) EC branches are suggested from semiempirical compilations of EC lifetimes [8] and have been observed for *all* of the other known nuclei with 153 neutrons above beta-stable ^{251}Cf, namely ^{252}Es, ^{253}Fm, ^{254}Md, ^{255}No, ^{256}Lr, ^{257}Rf, and ^{258}Ha. The nucleus ^{259}Ha is unknown and is expected to decay by alpha-particle emission (E_α predicted to be 9.0 MeV, $t_{1/2} \approx 1$ s) leading to known ^{255}Lr $\{E_\alpha = 8.43(40\%), 8.37(60\%), t_{1/2} = 22 \text{ s}\}$. The alpha decay of ^{255}Lr leads to unobservable products decaying by EC to long- lived ^{251}Cf as shown in Figure 2.

A reasonable scenario for our candidate and the sequence of events following it, is highlighted in Figure 2. An atom of element 110 is implanted in the appropriate focal plane detector with the correct values for relative energy loss (dE/dx), magnetic rigidity ($B\rho$), and deposited recoil energy (E); the alpha decay of $^{267}110$ is observed four microseconds later. We had planned to make use of a transient recorder to detect multiple events that occurred close together in time but, unfortunately, the necessary circuitry failed at the beginning of the runs. It was not possible to substitute equivalent equipment at that time so we had to make use of a "Second-ADC unit". This unit could record two events which happened within a few microseconds of one another but because of its resultant dead time of 280 microseconds, a third short-lived event, the alpha decay of ^{263}Hs, could not be observed. We suggest that the next member of the chain, ^{259}Sg, undergoes undetected EC to ^{259}Ha. Its decay is then manifested 6.0 s after the implantation by an alpha particle escaping in the backward direction through the detector face after depositing 2.2 MeV. Finally, 22-s ^{255}Lr decays 19.7 s after the implantation with the full alpha energy of 8.31 MeV. The lack of signals in this energy region for 900s following these correlated events is consistent with the chain of EC decays ending in long-lived ^{251}Cf. This single event would correspond to a production cross section of about one picobarn if all beam particles were deemed to be equally likely to produce it.

4. THE 8.1 MeV ALPHA PARTICLE

Twenty-six seconds before the element-110 event, there was an implantation in detector #28 that was 1.4 mm away from the implantation position of the element-110 event. At this site, an 8.1 MeV alpha particle was observed 26 seconds later, i.e., 150 ms after the implantation of the element-110 event. This 8.1 MeV alpha particle thus occurred in between (in time) the 11.6 MeV alpha particle and the 2.2 MeV escape alpha. We believe this rogue event is due to the implantation of ^{213}Fr ($t_{1/2} = 34.6$s), followed by the EC decay of ^{213}Fr to ^{213}Rn ($t_{1/2} = 25$ms) and the alpha decay of ^{213}Rn ($E_\alpha = 8.09$ MeV). As supporting evidence for this scenario we cite the observation in the lower portion of the focal plane array of a number of events in which 8.1 MeV alpha particles were preceeded by implantations of recoil atoms. These recoil atom-alpha decay time correlations were consistent with two different parents, a 35 s parent and a 25 ms parent.

5. DISCUSSION OF RESULTS

Let us review the evidence for the association of the observed event with the formation of $^{267}110$. The $B\rho$ and dE/dx of the implanted recoil are consistent with values expected for element 110. The recoil energy strongly indicates a CN recoil, rather than a transfer product. The 11.6 MeV alpha particle suggests either Z=110 or $^{212}Po^m$, the only known alpha-emitter with such a high decay energy. The probability of getting an accidental correlation between an implant and the 11.6 MeV alpha particle we have calculated to be 10^{-7}. The occurrence of an escape in the alpha-particle chain has a probability of occurrence of 0.45 and 2.2 MeV is the most probable energy expected for any escape alpha-particle. The probability of seeing the implant followed by the 11.6, 2.2 and 8.31 MeV alpha-particles due to an accidental correlation is 10^{-10}. Other than ^{255}Lr, only three nuclei [^{257}No, ^{256}Lr and $^{211}Po^m$] show the decay mode characterized by the emission of an 8.2–8.4 MeV alpha-particle followed by 900s of no decays. In the case of $^{211}Po^m$ there is a rare alpha group at 8.30 MeV with an abundance of only 0.25%.

On balance, the association of this event with the formation of element 110 appears to be the simplest explanation for our observations. Unfortunately, the SuperHILAC has been shut down and the SASSY2 separator has been dismantled, so that it is impossible for us to repeat the experiment in the very near future. In due time we hope to confirm our findings with a new separator at the LBL 88-Inch Cyclotron. We chose to report this information at this stage in the hope that it will be of value to others in the field.

We wish to acknowledge the outstanding performance of the SuperHILAC and its operations staff headed by H. Syversrud who produced and delivered ^{59}Co beams of as much as 1 pμa over this long period. We wish to thank K. Moody for helpful discussions regarding EC lifetimes. One of us would like to acknowledge the Norwegian Research Council for financial support. This work was supported in part by the Director, Office of Energy Research, Division of Nuclear Physics of the Office of High Energy and Nuclear Physics of the U.S. Department of Energy under Contract DE-AC03-76SF00098 and Grant DE-FG06-88ER40402.

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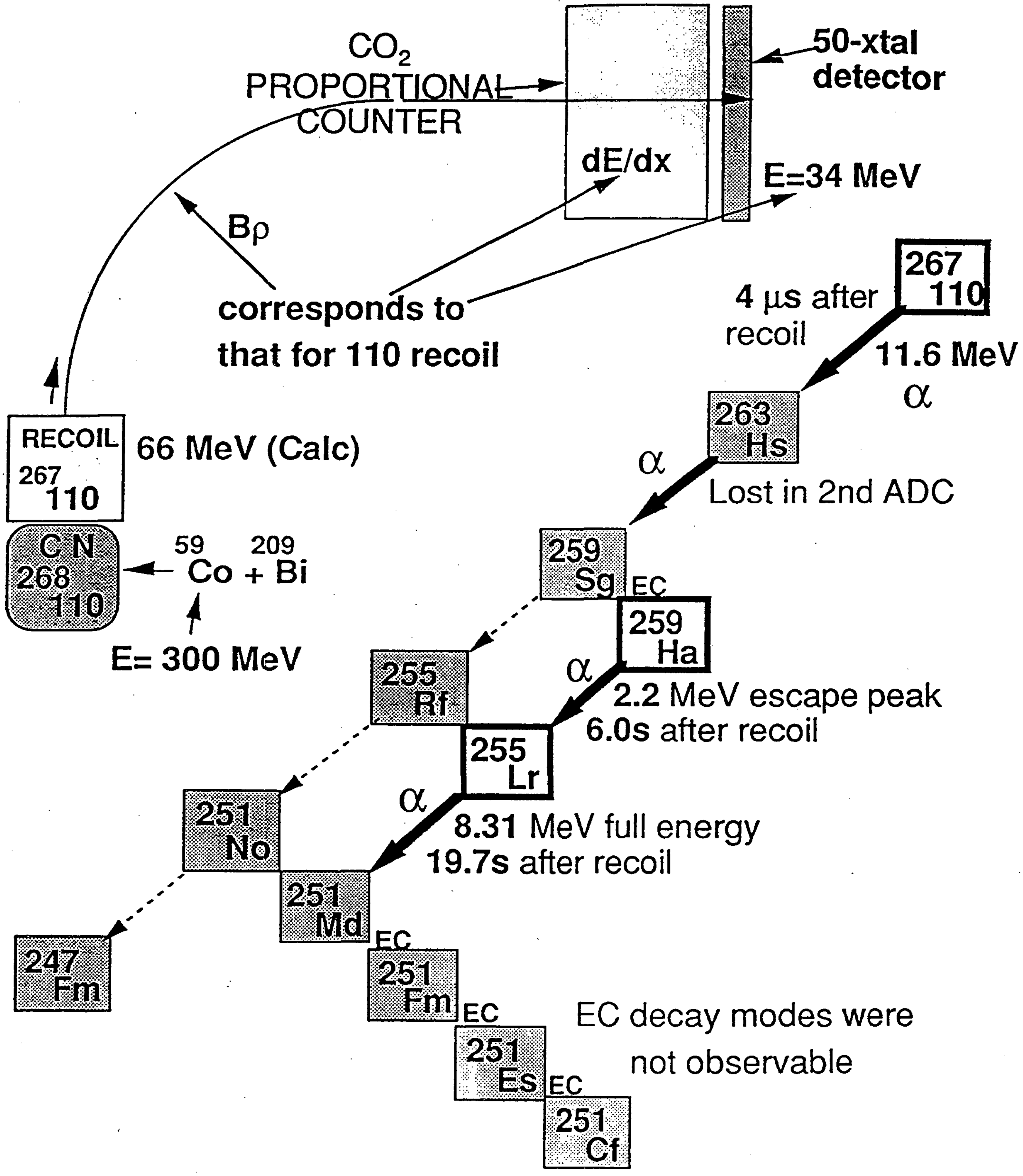

Figure 2. Proposed scenario for the element-110 event.

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