New Results on Element 111 and 112

S. Hofmann, F.P. Heßberger, D. Ackermann, B. Kindler, J. Kojouharova, B. Lommel, R. Mann, G. Münzenberg, S. Reshitko, H.J. Schött, GSI Darmstadt
A.G. Popeko, A.V. Yeremin, JINR Dubna
S. Antalic, P. Cagarda, S. Śaro, University Bratislava
H. Kettunen, M. Leino, J. Uusitalo, University Jyväskylä

The elements 110, 111, and 112 were first identified in a series of experiments in 1994 and 1996 at the SHIP velocity filter [1]. A total of 4 decay chains was measured of the isotope ^{269}110 and 9 decay chains of ^{271}110. Cross-sections of 3.5 and 15 pb, respectively, were determined. The cross-sections for element 111 and 112 were 3.5 and 1.0 pb, deduced from a total of 3 and 2 decay chains.

The new isotopes were identified by position and time correlation analysis. The data were obtained by using position-sensitive Si detectors (details of the experimental set-up and the analysis procedure are given elsewhere [2]). In order to prepare a safe identification of the ^{269}110 nucleus, the decay chain of the daughter ^{265}Hs and its excitation function were measured in a preceding irradiation. In the case of the isotope ^{271}110, the granddaughter ^{263}Sg was known from literature. Therefore the identification of these nuclei was straightforward and without a doubt. The discovery of element 110 by this work was recognized recently by a IUPAC/IUPAP Joint Working Party (JWP) [3].

Concerning the discovery of elements 111 and 112, the JWP concluded that further experiments are needed in order to fulfill the previously worked out criteria for assigning priority of discovery for these elements.

In order to confirm our previous results, we performed two experiments in 2000 aiming at new data on the synthesis and the decay pattern of ^{272}111 and ^{277}112. The irradiation took place from October 16 – 29 and May 3 – 29, respectively. The reactions were the same as in our first experiments, ^{64}Ni + ^{209}Bi → ^{273}111* and ^{70}Zn + ^{208}Pb → ^{278}112*. First results from the Z = 112 experiment were already published in [2]. Subsequent to the irradiation of ^{209}Bi with ^{64}Ni we irradiated a ^{207}Pb target aiming at the synthesis of the even-even nucleus ^{270}110. The results are presented in a succeeding contribution to this report.

In completion of the set-up used in our previous experiments, an electronic circuit was installed in the Z = 111 run, which allowed for switching off the beam within 50 μs after an implanted residue was detected by coincidence of energy and time-of-flight signal. In a subsequent time window of 10 ms a preset number of α particles (in this experiment one) was counted which then prolonged the beam-off period up to the expected measurable end of the decay chain. In our experiment 10 min were chosen, thus making provision for the detection of a possible α decay of ^{252}Md, $T_{1/2}$ = 2.3 min. This improvement considerably reduced the background and allowed for the safe detection of signals from long lived decays. The circuit was prepared already in May for the Z = 112 experiment, however, the trigger conditions could not be set properly, mainly due to the energy shift by degrader foils used in front of the detector.

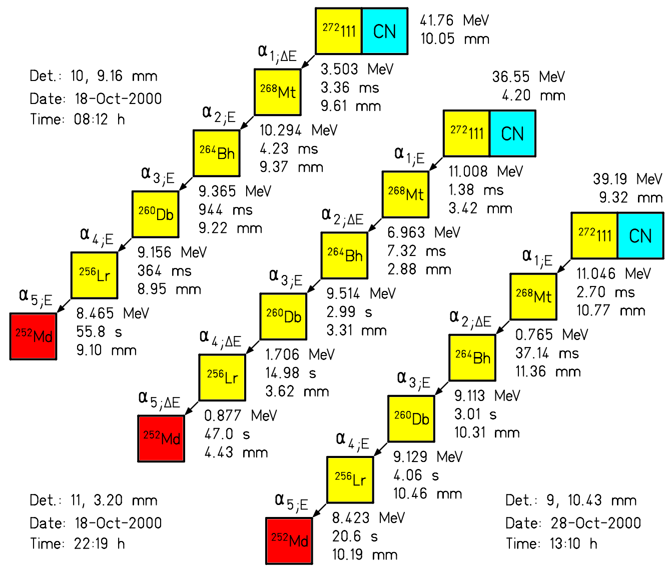

Figure 1: Decay chains and decay data measured during an experiment aiming at the confirmation of element 111.

The targets were prepared in the usual way, 450 μg/cm^2 lead or bismuth was evaporated on a 40 μg/cm^2 carbon foil. The targets were then covered by 10 μg/cm^2 carbon to protect the targets from sputtering and to improve radiative cooling.

The beam energy in the Z = 111 experiment was 320.0 MeV, the resulting excitation energy of the compound nucleus was 14.1 MeV using the mass tables of ref. [4]. At this energy we had measured 2 events in the first experiment during an irradiation time of 5.9 days (one chain was observed at 12.7 MeV excitation energy). A beam dose of 1.1×10^{18} had been collected from which a cross-section of $(3.5\ ^{+4.6}_{-2.3})$ pb resulted. In the new experiment the irradiation time was 13 days and the beam dose 2.2×10^{18} ions. A total of 3 decay chains was measured from which, in agreement with the first result, a cross-section of $(2.5\ ^{+2.5}_{-1.4})$ pb follows. The mean value from both experiments (5 events at $3.3\ \times10^{18}$ projectiles) is $(2.9\ ^{+1.9}_{-1.3})$ pb.

The decay data of the 3 chains measured in the October 2000 experiment are plotted in Fig. 1. A comparison with the 3 previously measured chains and with literature data is shown in Fig. 2. The most important results are summarized in the following: 1) The trigger for the switching off the beam worked properly. All three chains were measured in full length during beam-off periods. 2) In the case of two of the three new chains (chain 5 and 6) the full α energy was measured from the decay of ^{272}111. The two energy values agree, however, the mean value of 11.03

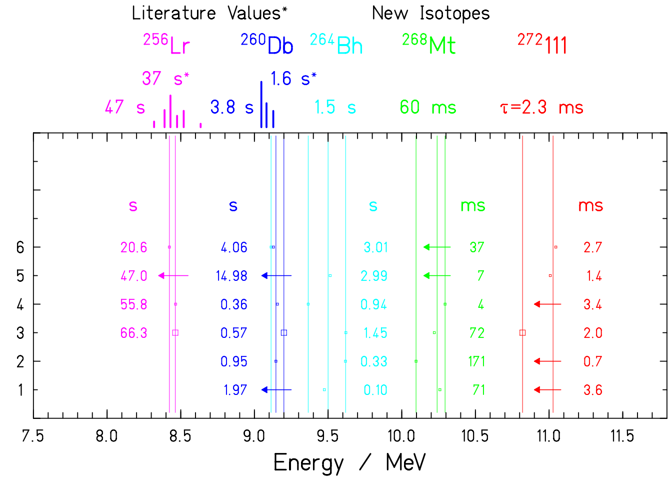

Figure 2: Comparison of α-decay data from the six events which were assigned to the decay of $^{272}111$. The event chains are chronologically ordered and numbered from 1 to 6. The size of the data points reflects the detector resolution, small dots stand for $\alpha's$ stopped in the main detector, larger squares for escape $\alpha's$ stopped in the back detectors and arrows for escape $\alpha's$ delivering only a ΔE signal from the main detector. Vertical lines are drawn at energies of single data points or at the mean energy values of transitions which have the same energy within the detector resolution. The single and mean values of lifetimes (not half-lives) are also given. Above the upper abscissa the α spectra deduced from literature are plotted for the decays of ^{256}Lr and ^{260}Db.

MeV is 0.21 MeV higher than the energy obtained from chain 3 of the first experiment. 3) The energies of the α decay of the daughter, ^{268}Mt, and granddaughter, ^{264}Bh, are spread across a wide energy range. Similar, even wider energy distributions were measured from the decay of the neighboring odd-odd isotopes ^{266}Mt and ^{262}Bh [5]. 4) A total of four α-energies was measured from the ^{260}Db decay. Three of them agree within the detector resolution. The mean value of 9.14 MeV also agrees with one of the 3 lines given in the literature. For this line energies of 9.14 and 9.12 MeV were reported [6, 7]. A slightly different, 60 keV higher energy was measured from chain 3. However, the energy value of 9.20 MeV was determined from an escape event stopped in the back detectors. For such events the energy resolution is only 40 keV (FWHM). 5) Six α lines in the energy range from 8.30 to 8.65 MeV are known from the decay of ^{256}Lr [6, 7]. Our energies from chain 3, 4, and 6 agree with the literature values. 6) The measured lifetimes agree for each of the nuclei and in the case of ^{260}Db and ^{256}Lr also with the literature values. There is only one exception. The decays of ^{268}Mt are spread across a larger lifetime period. Although the distribution is still in agreement with statistical fluctuations, it could also be possible that the longest (171 ms) or shortest (4 and 7 ms) lifetimes are related to decays from isomeric states.

Our conclusion of the recent Z = 111 experiment is that our first results are confirmed and that the new data reveal considerably improved information on the decay pattern of the chains starting at $^{272}111$.

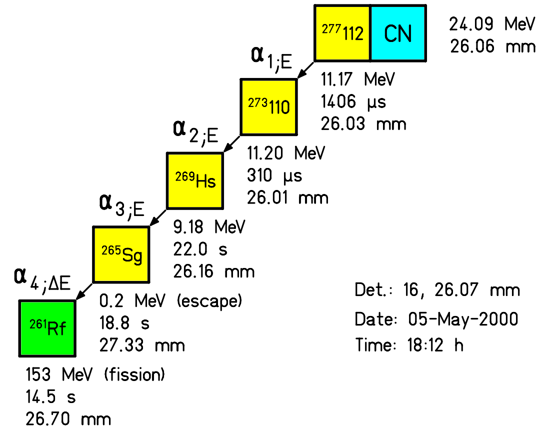

Figure 3: Decay chain of $^{277}112$ measured during a recent experiment aiming to confirm element 112.

In the study of the reaction for the synthesis of element 112 we used a beam energy of 346.1 MeV. The resulting excitation energy of 12.0 MeV is 2.0 MeV higher than in our first experiment. During an irradiation time of 19 days we collected a total of 3.5×10^{18} projectiles. One decay chain was observed. The measured data and our assignment are given in Fig. 3. The first two α decays have energies of 11.17 and 11.20 MeV, respectively, which are succeeded by an α of only 9.18 MeV, an energy step by about 2 MeV. Correspondingly, the lifetime increases by about five orders of magnitude between the second and third α decay. This decay pattern is in agreement with the one observed for chain 2 in our first experiment. It was explained as the result of a local minimum of the shell correction energy at neutron number N = 162 which is crossed by the α decay of $^{273}110$.

The α energy of 9.18 MeV for the decay of ^{269}Hs is identical within the detector resolution with the value of 9.17 MeV obtained in chain 1 of our previous experiment. A new result is the occurrence of fission ending the chain at ^{261}Rf. Fission was not yet known from ^{261}Rf, but is likely to occur taking into account the high fission probabilities of the neighboring even isotopes.

A cross-section of $(0.5^{+1.1}_{-0.4})$ pb was measured for the new data point at 12.0 MeV excitation energy. This value fits well into the systematics of cross-sections. A cross-section increase with increasing beam energy as predicted by theoretical investigation [8] was not observed.

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