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An Experimental Survey of the Production of Alpha-Decaying Heavy Elements in the Reactions of ^{238}U + ^{232}Th at 7.5-6.1 MeV/Nucleon

Using the energy of alpha particles and their times to search for new heavy isotopes

THE SCIENCE

A so-called heavy element "island of stability" has been predicted for many years. Experiments that provide the possibility of producing elements that have atomic numbers of nuclei predicted to be on that island of stability can constrain existing nuclear models and may reveal new phenomenon. Understanding the properties of heavy elements can also provide important information on understanding relativistic effects in the electron structure.

THE IMPACT

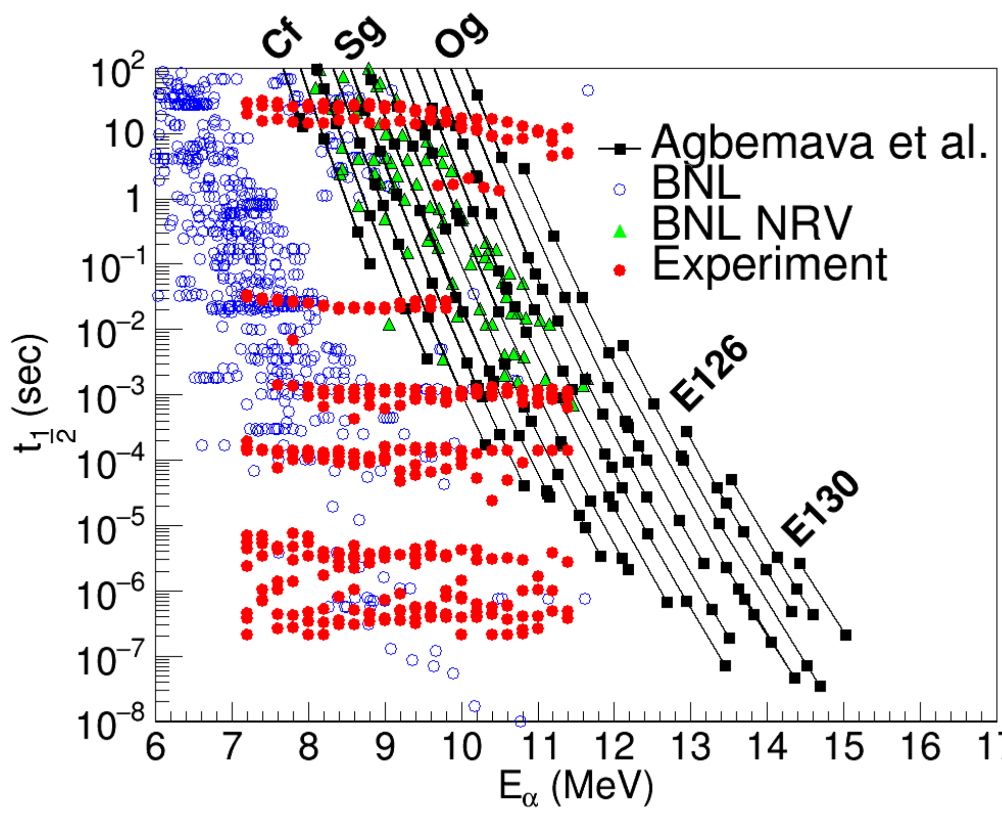
We have embarked on a search for super heavy elements using the mechanism of multinucleon transfer reactions of very heavy nuclei which may provide an enhancement in the yields of heavy neutron rich nuclei. In this way we allow nature to select the neutron richness of the elements produced. We also leverage the property that the energies of alpha particles emitted in the decay of heavy elements generally increase with increasing atomic number.

SUMMARY

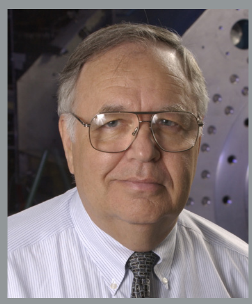
There is significant activity in heavy ion nuclear science to search for super heavy elements. The nucleus with the largest atomic number discovered to date is Oganesson, having an atomic number of 118. Due to increasingly low cross-sections, that is, increasingly low probabilities of producing heavier and heavier elements, the complete fusion reaction method of searching for super heavy elements requires extremely time consuming searches which is, in turn, very expensive. Furthermore, the predicted island of stability suggests that stable heavy elements are more neutron rich than can be easily produced directly in such fusion reactions.

Our group at the Texas A&M Cyclotron Institute, along with collaborators, has constructed an apparatus to allow such a search in an extremely efficient manner. The device is a so called active catcher array which is placed a small distance downstream of the target to collect heavy elements that may be produced in 7.5 MeV/u U + Th reactions. This catcher is itself a detector in that it can detect alpha particles that may be released from the decay of the implanted heavy elements. We employ waveform digitizers along with a variety of clocks to determine the time when the alpha particles are emitted as well as their energies. Using this information, we determined energies and half-lives for elements that were caught in the active catcher.

The correlated energy-half-life results of our search are used to determine the atomic of the nuclei from which these alpha particles were emitted. The results indicate that the heaviest elements observed have the longest half-lives and that the atomic numbers of elements that we observed with shorter half-lives do not extend to such heavy elements. To ascertain the range of the atomic numbers of these nuclei, we compare the data to theoretical predictions that were done for several isotopes of heavy elements having atomic numbers that range from some of the heaviest discovered to date to some far in excess of those discovered to date. Comparisons of the energies and half-lives of these alpha emitters with known and predicted half-lives suggest that new activities with Z as high as 116, and perhaps higher, are being produced in these reactions. Further, more detailed investigations are needed to verify these results.



Total Half-life, seconds vs E_α, MeV for activities with $t_{1/2} \leq 100$ seconds. Open circles – known alpha half-lives for isotopes with Z to 101, solid diamonds – NRV tables and BNL tables data for isotopes with Z > 101, solid black squares connected by lines depict predictions of partial alpha-lifetimes versus E_α for even-even nuclei, left to right Z=98 to 130. Data for different time ranges are represented by red closed circles.



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PUBLICATIONS

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ABOUT THE CYCLOTRON INSTITUTE: *Dedicated in 1967, the Cyclotron Institute serves as the core of Texas A&M University's accelerator-based nuclear science and technology program. Affiliated faculty members from the Department of Chemistry and the Department of Physics and Astronomy conduct nuclear physics- and chemistry-based research and radiation testing within a broad-based, globally recognized interdisciplinary platform supported by the United States Department of Energy (DOE) in conjunction with the State of Texas and the Welch Foundation. The facility is one of five DOE-designated Centers of Excellence and is home to one of only five K500 or larger superconducting cyclotrons worldwide.*