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Formation of a ^{7}Be Plasma

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Abstract. ^{7}Be is an isotope of beryllium that decays by electron capture to ^{7}Li. Because the energy of decay is too small for electron-positron production, electrons must be present for ^{7}Be to decay. It is possible to modify the rate of decay by changing the effective electron density in the region of the nucleus. As part of our effort to study the effect of ionization on the decay rate we will confine a uniformly-ionized non-neutral ^{7}Be plasma for sufficiently long periods to determine the change in the decay rate as a function of ionization state. The ^{7}Be is formed by proton bombardment of a B_4C target containing ^{10}B. In order to form the plasma the ^{7}Be must be extracted from the B_4C matrix, ionized, and inserted into the trapping region with as little boron, carbon, or lithium contamination in the final plasma as possible. We are currently investigating several possible techniques for forming a ^{7}Be plasma. Some of the possibilities are evaporation followed by e-beam ionization, laser ablation, and electric discharge.

INTRODUCTION

^{7}Be is a radioactive isotope with a half-life of 53.29 days which decays to ^{7}Li through electron capture. The decay energy of 0.862 MeV is insufficient to produce a positron–electron pair so decay is only possible through electron capture. Of these decays 10.7% will produce a 477.6 keV gamma ray. The remainder will not produce any detectable products other than the ^{7}Li daughter nucleus.

Because ^{7}Be only decays by electron capture it is possible to modify the rate of decay by modifying the electron density in the vicinity of the nucleus. Several groups have recorded measurable changes in the rate of decay. The effects of chemical bonding show changes of up to 0.08% in BeF_2 [1,2]. BeO at a pressure of 270 kbar exhibits a change of 0.59% in the decay rate [3]. Ionization of ^{7}Be should also modify the rate of decay. It is estimated that removal of the 2s electrons will reduce the rate of decay by roughly 3% while removal of one of the 1s electrons will reduce the rate by approximately 45%. A fully ionized ^{7}Be atom should be stable as long as it can't capture an electron from a neighboring atom.

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MEASURING THE EFFECT OF IONIZATION

The ideal device for measuring the effect of ionization on the decay rate of ^{7}Be is an ion Malmberg-Penning trap. Such devices are now routinely used to confine ion plasmas for periods of weeks. These devices also allow the use of Fourier Transform Ion Cyclotron Mass Spectrometry (FT-ICR/MS) to measure the amount of ^{7}Li that has been produced in the plasma as a function of time. This would require a mass resolution of greater than 8000 - a value that is commonly achievable in FT-ICR/MS systems. The alternative to FT-ICR/MS for detecting the decays would be to measure the rate at which 477.6 keV gamma rays are produced but the geometry of an ion trap will restrict the solid angle of detection to the point that it will be very difficult to achieve good statistics.

We are currently building a device that will confine about 10^9 ions in a 0.5 T magnetic field in a Malmberg-Penning configuration. This will result in a neutral decay rate of about 150/second with a rate of decay in a triply-ionized plasma of approximately 83/second. The sensitivity of FT-ICR/MS would be adequate to detect the presence of ^{7}Li within a few seconds and to make accurate measurements within a few hours.

PRODUCTION OF ^{7}BE

^{7}Be is produced in the atmosphere by spallation reactions from the interaction of cosmic rays with nitrogen and oxygen atoms. It is also produced in the core of the sun through a ^{3}He+^{4}He fusion reaction. For laboratory use ^{7}Be is commercially available from several sources. However, this ^{7}Be is contaminated with significant amounts of ^{7}Li due to processing and shipping delays making detection of small changes in the decay rate more difficult. Removal of the trace ^{7}Li is not possible because of the very small mass difference between the two isotopes. A more pure sample of ^{7}Be can be produced in the laboratory by proton bombardment of ^{10}B through the reaction

$$^{10}B(p,\alpha)^7Be.$$

The rate for this reaction is significant for proton energies above about 250 keV. We are using a 400 keV van de Graaff accelerator to bombard a target of ^{10}B-enriched B_4C [4] and produce ^{7}Be. Because of the presence of ^{11}B and ^{12}C in this target there are four other possible reactions at this energy:

$$^{10}B(p,\gamma)^{11}C \rightarrow {}^{11}B + \beta^+ + \nu_e$$
$$^{11}B(p,\alpha)^8Be \rightarrow 2\alpha$$
$$^{11}B(p,2\alpha)^4He$$
$$^{12}C(p,\gamma)^{13}N \rightarrow {}^{13}C + \beta^+ + \nu_e.$$

The cross-sections for these reactions are all significantly smaller than that for the production of ^{7}Be. The two β-decay reactions are relatively fast (half lives of 20.39

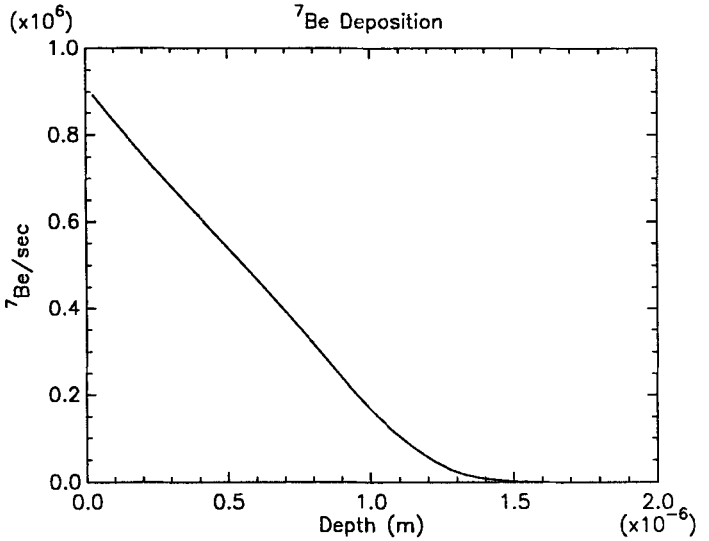

FIGURE 1. The predicted rate of deposition of ^{7}Be as a function of depth in the B_4C target for 100 μA of 300 keV protons.

minutes and 9.965 minutes respectively) and the two α-decay reactions are almost instantaneous. The resulting products of all four reactions will not be difficult to remove from the plasma during the formation and confinement phases. As can be seen in figure 1, the majority of the resulting ^{7}Be will be deposited within about 1.5 μ of the surface of the target with about half of it within 0.35 μ of the surface. At a proton energy of 300 keV we also found that about 7% of the ^{7}Be is ejected from the front of the target and deposited on the surrounding surfaces. This is about twice as much as we expected from the recoil of energetic ^{7}Be atoms. It may be enhanced by local heating of the target by the proton beam causing some of the beryllium to evaporate.

EXTRACTION OF ^{7}BE

Several methods of extracting the ^{7}Be from the B_4C target have been proposed, including thermal evaporation, e-beam evaporation, sputtering, electrical discharge, and laser ablation. The primary difficulty is that the beryllium constitutes an impurity in the target at a level of roughly 1 part in 10^8. At present we have only been able to test extraction using thermal evaporation. The B_4C target was placed in a loop of tungsten wire and heated for about 30 minutes. The stainless steel plate that was placed above the target to catch any evaporated ^{7}Be showed no trace of radioactivity when checked for 477 keV gamma rays but the activity of the target itself was decreased by about 25% indicating that some of the beryllium

was evaporated out of the target but it either did not come out of the target in the expected direction or it did not stick to the stainless steel plate. It is not known if the beryllium came out of the target slowly over the 30 minutes or if it all came out in a short period at the start.

CONCLUSION

It is clear that the production of ^{7}Be is well understood. From our experience with thermal evaporation it appears that this method of extracting the ^{7}Be is probably too inefficient and too slow to allow us to reliably form and confine a beryllium plasma. It is probable that e-beam evaporation and sputtering will suffer from the same difficulties as thermal evaporation. Laser ablation of the surface of the target appears at this point to offer the most promise in achieving a reliable plasma formation for the population of the ion trap.

REFERENCES

1. Leininger, R. F., Segrè, E., and Wiegand, C., *Phys. Rev.*, **76**, 897-898 (1949).
2. Kraushaar, J. J., Wilson, E. D., and Bainbridge, K. T., *Phys. Rev.*, **90**, 610-614 (1953).
3. Hensley, W. K., Bassett, W. A., and Huizenga, J. R., *Science*, **181**, 1164-1165 (1973).
4. The B_4C was an engineering sample enriched to 80% ^{10}B obtained from Eagle-Picher Industries, Inc., Boron Department, P.O.Box 798, Quapaw, OK 74363.