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Author

Morrissey, D.J.

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D. J. Morrissey, W. Loveland and G. T. Seaborg

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Implications of the Target Residue Mass and Charge Distributions in the Interaction of 8.0 GeV ^{20}Ne with ^{181}Ta*

D. J. Morrissey, W. Loveland† and G. T. Seaborg

Lawrence Berkeley Laboratory
and Department of Chemistry
University of California
Berkeley, California 94720

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†Permanent address: Department of Chemistry, Oregon State University, Corvallis, Oregon 97331.

IMPLICATIONS OF THE TARGET RESIDUE MASS AND CHARGE DISTRIBUTION IN THE INTERACTION OF 8.0 GeV ^{20}Ne WITH ^{181}Ta

Abstract

Target residue mass and charge distributions have been measured radioanalytically for the reaction of 8.0 GeV ^{20}Ne ions with Ta. These distributions are very similar to those distributions observed in the reaction of Ta with protons of equivalent total energy rather than equivalent velocity. Detailed comparisons of the production cross sections for near target residues with abrasion-ablation model calculations show these products to have an excitation energy of ~75 MeV.

Introduction

Previous studies of the target residues from relativistic heavy ion (RHI) reactions, particularly with heavy targets,[1,2] revealed the production of nuclei with masses greater than half the target mass. These residues were studied in the interaction of 25 GeV ^{12}C with Cu[3], Ag[4], Au and Pb[2] and U[1], as well as 80 GeV ^{40}Ar with Cu[5]. Comparison of the measured mass and charge distributions of these "target residue nuclei" with predictions of the simple clean-cut picture of the abrasion-ablation model[6,7] indicated that many of these nuclei were the survivors of the primary target-projectile encounter and, furthermore, some of these nuclei resulted from encounters with impact parameter $b < 0.7\ (R_t + R_p)$. It is common when discussing projectile fragmentation processes in RHI reactions to describe experiments in terms of the projectile velocity (i.e., 2.1 GeV/amu, etc.).[8] Measurements by Cumming et al.[3,5] have shown that the isotope production cross sections, $d^2\sigma/dZdA$, for the interaction of RHI's with Cu targets compare most favorably with isotope production cross sections from reactions induced by protons of equivalent total energy. In view of the observed difference between RHI reactions with low mass and high mass targets,[1,3] and the larger volume to surface ratio in the heavy nuclei, we felt it was important to study the relative importance of velocity and total energy in RHI interactions with heavy nuclei. The previously observed dramatic differences in $d\sigma/dA$ for the reaction of Ta with 340 MeV protons[9] and with 5.7 GeV protons[10] can be seen in figure 1.

We report in this paper the results of measurements of the production cross sections of these heavy target residues from the reaction of 8.0 GeV (400 MeV/amu) ^{20}Ne with Ta. We also report the results of detailed calculations of the mass and charge distributions for this reaction with the abrasion-ablation model.

Experimental

A Ta foil (of thickness 164.6 mg/cm^2 surrounded by 5.4 mg/cm^2 mylar catcher foils) was irradiated for 247 minutes in a beam of 8.0 GeV ^{20}Ne ions of intensity ~1.64×10^{10} particles/min at the Lawrence Berkeley Laboratory Bevalac. Gamma-ray spectrometric measurements of the radioactivity induced in the target and catcher foils began 14 hours after bombardment and continued for about five weeks. Approximately 60 radionuclides were identified in this study on the basis of their γ-ray energy, half-life and radiation abundances.[11] Using the procedures described elsewhere,[12] independent yield formation cross sections, $d^2\sigma/dZdA$, were calculated for all radionuclides. This was accomplished by correcting for precursor decay through iterative fitting [of Gaussian charge dispersions of the form $P(Z,Zp) = (2\pi\sigma_Z{}^2)^{-1/2} \exp(-Z-Zp)^2/2\sigma_Z{}^2)$] to the corrected data.

Results

Comparison of the mass yield data from the RHI and proton induced reactions in Fig. 1 shows the dramatic agreement between the mass distributions of 8.0 GeV ^{20}Ne and 5.7 GeV protons. The total integrated cross section for species with $A > 40$ is 2.5 barns. Using the Bradt-Peters geometrical form for the reaction cross section,[13] $\sigma_R = \pi r_o{}^2(A_1{}^{1/3} + A_2{}^{1/3} - b)^2$, and the parameters obtained by Heckman et al.[8] for $A_1 = 20$, $r_o = 1.37$ fm and $b = 0.51$, one obtains a reaction cross section of 3.64 barns. Thus, our results set an upper limit on the extent of central projectile-target collisions in which no survivors (with mass number $A > 40$) occur at <30% of the total reaction cross section. Also shown by the dashed curve in Fig. 1 is the prediction of the abrasion-ablation model for the product mass distribution for this reaction.[6,7] Primary residues or target spectators are those fragments that remain after the overlap region between the two sharp spheres is removed from the target nucleus by the interaction (abrasion). These primary residues are assumed to have an excitation energy due to the increased surface area of the distorted fragments,[6] and are de-excited through a statistical evaporative cascade with

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fission competition[7] (ablation). Figure 1 shows that the shape of the target residue distribution is correctly predicted by this model (indicating that the shape of this distribution is largely governed by geometrical factors), but the magnitude of the cross section is overestimated by a factor of two.

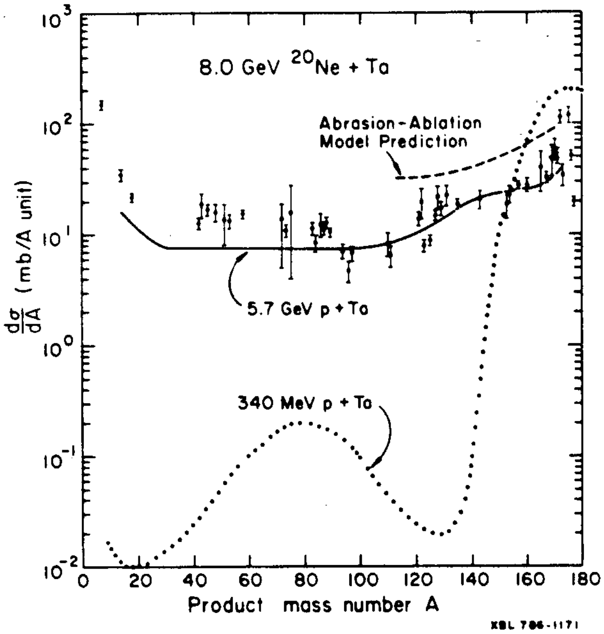

Fig. 1. Product mass distribution from the reaction of 8.0 GeV ^{20}Ne with Ta. For explanation see text.

Conclusions

Thus, our results show that the total energy of the incoming projectile, rather than its velocity, appears to determine the production of target residue nuclei from high mass targets, as was the indication for Cu targets.[3,5] Further, the predictions of the simple clean-cut picture of the abrasion-ablation model do not work as well at 400 MeV/amu as at 2.1 GeV/amu, in fact overestimating the production cross sections at the lower energy. And finally as our data show, it appears that some of the target residue nuclei are produced in interactions involving significant overlap of the central densities of projectile and target ($b \sim 0.55\ (R_p + R_t)$). These "hard" collisions would appear to offer exciting opportunities to study new aspects of nuclear reaction dynamics. The authors would like to thank their colleagues Roland J. Otto and Michel de St. Simon for their assistance in data taking, and for many helpful discussions in the course of this work.

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