DISTRIBUTION OF PRODUCTS IN THE REACTION ^{20}Ne + Al*

CONF-800329--2

R. L. Ferguson, A. I. Gavron, F. E. Obenshain, F. Plasil,
R. L. Robinson, D. Shapira, A. H. Snell and G. R. Young
Oak Ridge National Laboratory
P. O. Box X, Oak Ridge, Tennessee 37830

We report here our measurement and preliminary analysis of the distribution of products with $2 < Z < 21$ and $3 < A < 43$ from reactions of ^{20}Ne with Al. Experimental conditions were adequate to allow resolution of individual isotopes over this entire range, and measurements were made at several angles for each of two bombarding energies. Measured relative cross sections of the heavier products are compared with predictions of a statistical model evaporation calculation.

The measurement of distributions of evaporation residues (ER) with simultaneous single charge and mass resolution provides a sensitive test of evaporation models. In a systematic study of fusion reactions, it is possible to test various assumptions involved in the calculations, as well as to obtain values for various nuclear parameters. Information can be obtained, for example, on the variation of level density parameters with nuclear deformation and on deformation-enhanced particle emission. Effects of incomplete fusion may also be apparent in the observed distributions.

Experiments were performed using energy-analyzed, well-collimated beams of ^{20}Ne from the Oak Ridge Isochronous Cyclotron incident on 100 μg-cm^{-2} aluminum targets. For reaction products, the flight time was measured between two channel-plate electron multiplier assemblies 122 cm apart, and the energy loss in a gas-filled ionization chamber as well as residual energy in a silicon surface-barrier detector were also determined. Our time resolution of $\sim$ 150 ps FWHM and energy resolution of $\sim$ 0.6-MeV FWHM (measured for elastically scattered ^{20}Ne) gave a mass resolution of $\sim$ 0.4 FWHM. Resolution in Z was $\sim$ 0.6 FWHM. Differences in charge-collection times in the parallel plate ΔE ionization chamber were used to correct for small differences in path length between the channel-plate detector foils, which were oriented at 45° with respect to the detected particle's flight path. The data were analyzed by first constructing Z-masks in the ΔE-vs-E plane and then forming maps of an ET^2 function vs E for each Z. From these maps, A-masks were constructed, and an energy spectrum of each isotope was projected. Our present results are presented as relative yields.

Figure 1 indicates the energy- and angle-integrated yields of the observed products. As is to be expected, yields of the heaviest products from the 167-MeV bombardment can be seen to lie further from the compound nucleus than in the 118-MeV case.

In Fig. 2 are shown comparisons between our experimental results for the heavier products and the ER yields that are predicted by the evaporation code JULIAN (as modified by Gavron).[1] The calculated values have been normalized to experiment by the ratio of total experimental to theoretical σ_{ER}. For this purpose, the experimental σ_{ER} was defined to be the sum of yields for all nuclides with $Z \geq 12$ and $A \geq 24$.

The Monte Carlo evaporation code JULIAN (Hillman and Eyal), as modified by Gavron, includes proper angular momentum coupling to final states. The calculations shown were performed with the code's default options, which include: (i) Gilbert-Cameron level densities, (ii) the Bass model fusion cross section, (iii) the Cohen-Plasil-Swiatecki rotating liquid drop yrast line, and (iv) nuclear masses from the Wapstra 1977 table. One thousand cascades were calculated for each bombarding energy.

As is apparent in the Z and A projections of these comparisons (Fig. 3), the overall agreement between experiment and theory is rather good. With the calculational parameters used, the theoretical distribution is somewhat narrower than the experimental, both in Z and A at both bombarding energies. Variation of the input quantities will very likely improve the agreement. Hopefully, such variations will enable us to define level densities and the yrast line appropriate to this case, but it remains to be seen whether a unique fit can be obtained.

It is likely that even with the variations in input conditions mentioned above, it may not be possible to remove the discrepancies between calculation and experiment for low Z and A at 167 MeV. Lehr et al.,[2] were able to account for a similar underprediction of yield for light ER in their study of the system $^{20}Ne + ^{26}Mg$ by including the effect of incomplete fusion in the reaction. It may, of course, be possible that we are seeing a corresponding effect here. The underprediction of yield for heavier ER, especially noticeable at 118 MeV, could be due to an overemphasis on α-emission. In this case, agreement between experiment and calculation is likely to improve with other choices of input conditions.

We have also made comparisons with the computer code ALICE,[3] which does not involve the couplings to all final angular momentum states but treats angular momentum removal by particle emission only approximately. The purpose was to see if such a calculation, which requires less computing time than JULIAN, can give a rough description of the observed yields. It was found that ALICE results in distributions that have much higher Z and A values, and the effect is easily understood in terms of an underestimation of α-emission. We conclude that for such light systems ALICE calculations are inappropriate.

REFERENCES

1. A. Gavron, Phys. Rev. C 21, 230 (1978).
2. H. Lehr, W. v. Oertzen, W. Bohne, H. Morgenstern, K. Grabisch, and F. Pühlhofer, Hahn-Meitner-Institut für Kernforschung Berlin, Preprint HMI-P 1/80.
3. F. Plasil, Oak Ridge National Laboratory Report ORNL/TM-6054 (1977).

*Research sponsored by the Division of High Energy and Nuclear Physics, Office of Energy Research, U. S. Department of Energy, under contract W-7405-eng-26, with the Union Carbide Corporation.

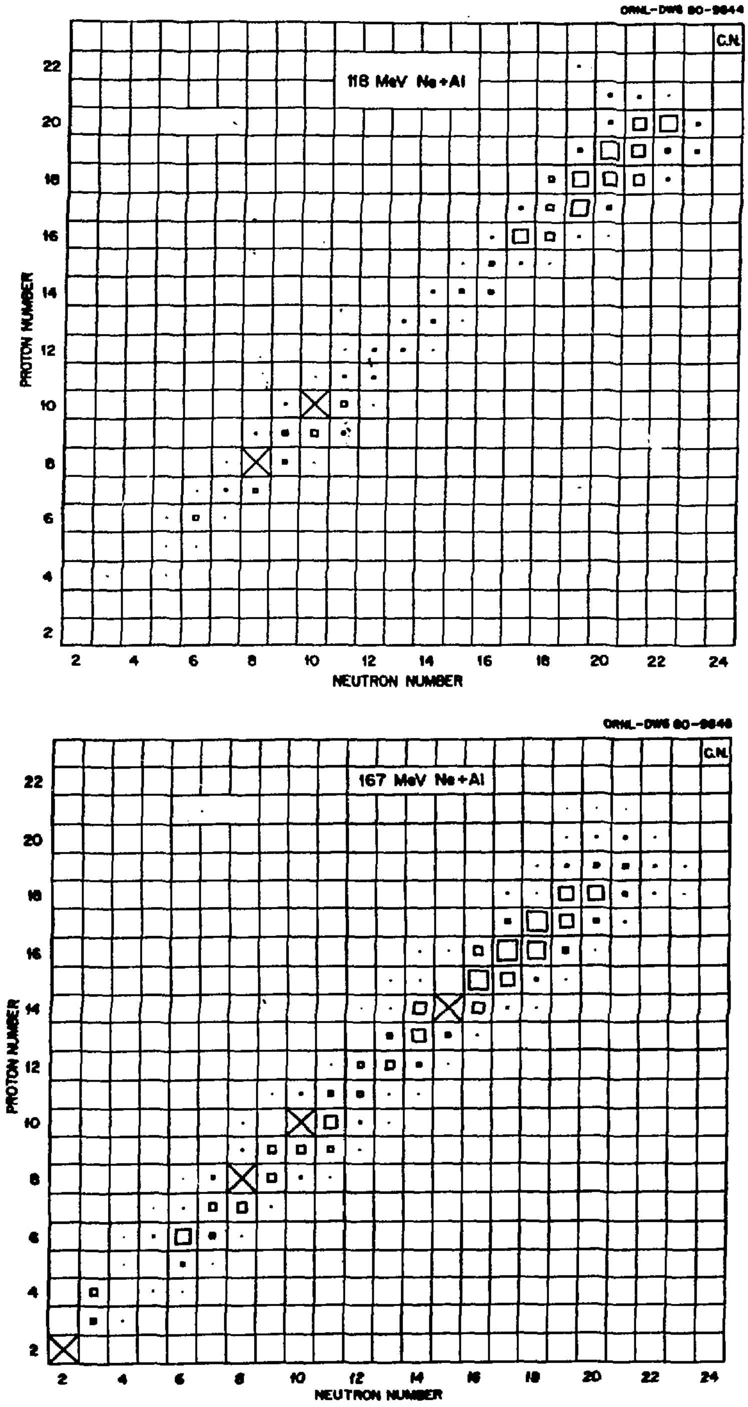


Fig. 1. Yields of all observed products from the reactions studied. Relative yields are proportional to the length of the side of the squares. The X's represent "overflow" values in the scale chosen.

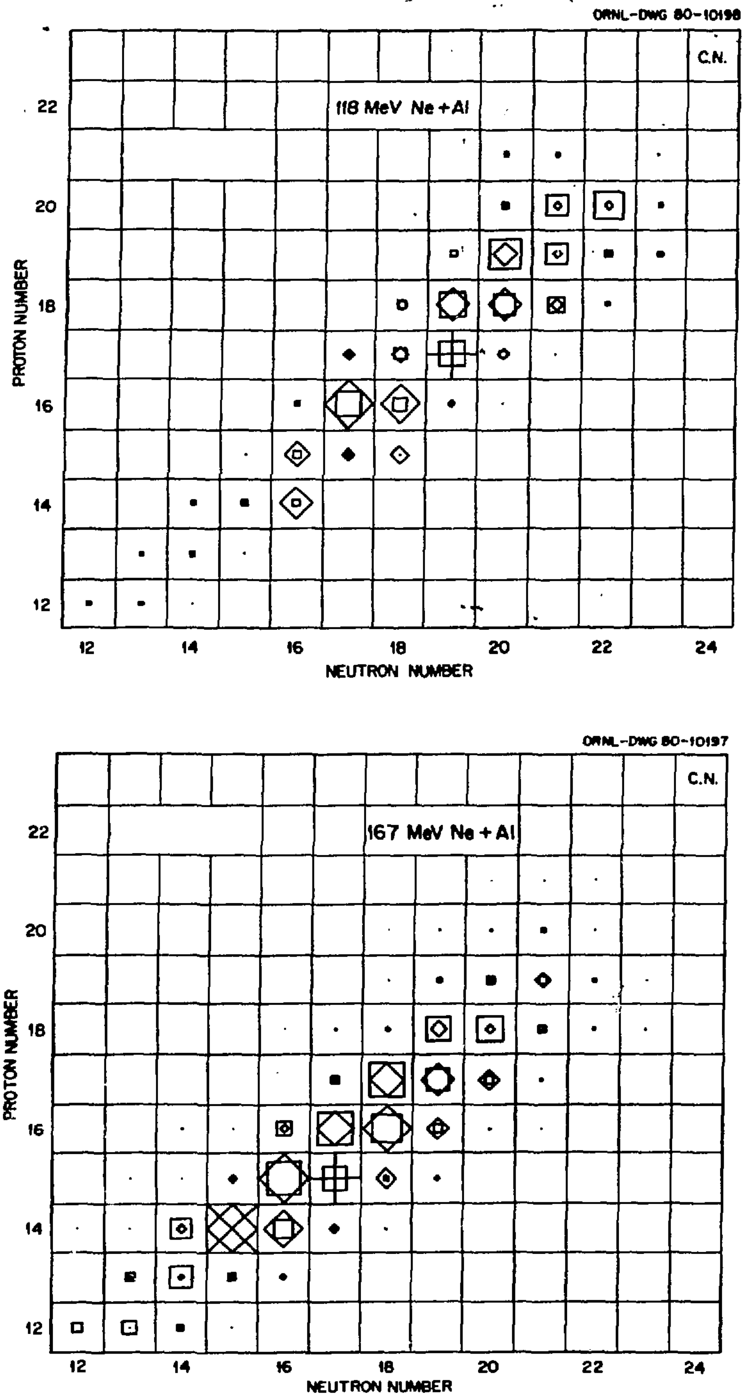
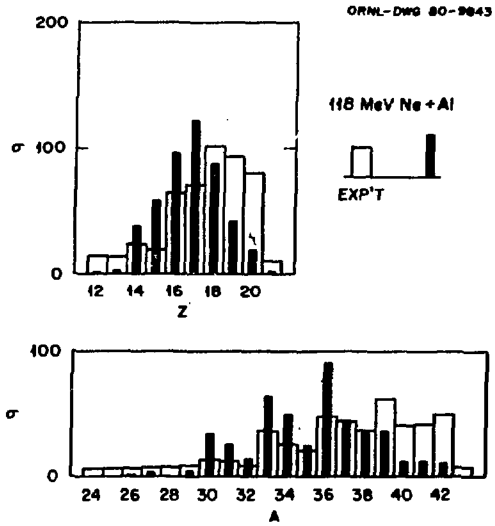


Fig. 2. Comparisons between measured yields (□,X) and Monte Carlo evaporation calculations (◇,+). Cf. Fig. 1.



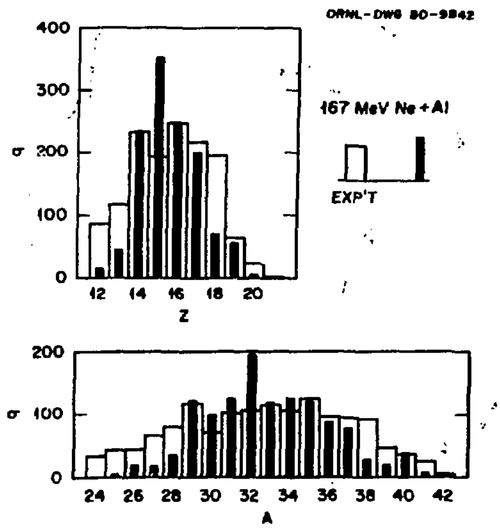


Fig. 3. Comparisons between experiment and calculations summed over A or Z to give the respective Z or A distribution.