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COMMENTS

Comments are short papers which comment on papers of other authors previously published in the **Physical Review**. *Each Comment should state clearly to which paper it refers and must be accompanied by a brief abstract. The same publication schedule as for regular articles is followed, and page proofs are sent to authors.*

Comment on "Unexpected large deformations in ^{60}Ni* nuclei produced in the reaction 120 MeV ^{30}Si+^{30}Si"

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A recent statistical-model analysis of La Rana *et al.* has indicated an extremely large deformation in the decay of the compound nucleus ^{60}Ni*, formed in the reaction ^{30}Si+^{30}Si at $E_{\rm lab}=120$ MeV. We believe that their calculations do not support the reported magnitude of reduction in the evaporation Coulomb barrier of the emitting system. By means of a statistical-model calculation, we show that most of the features of their data can be reproduced, assuming spherically symmetric parameters.

La Rana *et al.*[1] have recently reported on a study of energy and angular distributions of evaporative ^{4}He emission in the reaction ^{30}Si+^{30}Si at 120 MeV. The compound nucleus ^{60}Ni* was produced at an excitation energy of 75 MeV. The reported alpha-particle energy spectra were measured, in the singles mode, at the laboratory angles of 35°, 45°, 55°, 75°, 120°, and 150°. The measured spectra were compared to the predictions of statistical-model calculations assuming emission from spherical nuclei. Large discrepancies were found between the experimental and calculated spectra. A good description was obtained by reducing both the emission barrier and the entrance channel spin. Such modifications, incorporated in a simulation code, suggested emission from an oblate shape with an axis ratio of ≈3:1.

Excitation functions of evaporation residues and deduced n, p, and α multiplicities, for the same reaction, have been measured by Bozek *et al.*[2] in the excitation energy range of 42.3–63.1 MeV in ^{60}Ni*. Comparison of their data[2] with statistical-model calculations and standard parameters shows that the model *does* account for the general features of their data. The critical angular momentum for fusion at the highest bombarding energy[2] was estimated from the measured fusion cross section as $L_{\rm fus}\approx 33\hbar$. One could expect some angular-momentum-induced effect at the higher bombarding energy of La Rana *et al.* However, $L_{\rm fus}$ at their bombarding energy[1] is limited to $\approx 34\hbar$. This limitation has been observed in the fusion data of Dumont *et al.*,[3] which concern the ^{30}Si+^{30}Si reaction in the bombarding energy range of 55–126 MeV. Therefore, it is surprising that the statistical-model description of the effect claimed by La Rana *et al.* (and attributed to angular-momentum-induced deformations) requires the reported drastic modifications.

We proceed with the description of our calculations, justifying the parameters used. The statistical-model calculations were performed with a modified version of the code PACE.[4,5] Our version involves a reconsideration of the treatment of optical-model transmission coefficients (T_l) for charged-particle emission by the old code. This was dictated by cases, like this one, where conclusions have to be drawn from the behavior of data below the evaporation Coulomb barrier. Instead of the previously used extrapolation procedure,[5] complete optical-model calculations were performed for proton and alpha emission. Calculations were performed for isotopes in a 20×10 (N,Z) grid, chosen to include the range of isotopes considered in the statistical-model calculation. They were performed in the energy ranges of 2–32 MeV for protons and 3–33 MeV for alpha particles in steps of 1 MeV. Such sets of T_l for each energy and type of emitted particle were stored in computer files to be read by PACE. Transmission coefficients for nonintegral energy values were calculated internally from the input integral values by a logarithmic interpolation. For neutrons, the internal calculation employed by PACE was retained. In the optical-model calculations, we used the parameters of Wilmore and Hodgson[6] for neutrons, Perey and Perey[7] for protons, and Huizenga and Igo[8] for alpha particles.

Since the entrance channel consists of two identical spin-zero bosons, symmetrization makes all odd partial waves vanish from the scattering amplitudes. The compound nucleus angular momentum distribution is then given by

$$\sigma_L=\pi\lambda\!\!\!^{-2}(2L+1)[1+(-1)^L]$$
$$\times\{1+\exp[(L-L_{\rm fus})/\Delta]\}^{-1}\,.$$

$L_{\rm fus}$ was determined by the requirement that $\sum \sigma_L$ reproduces the fusion cross section $\sigma_{\rm fus}$ with an assumed diffuseness parameter $\Delta = 2\hbar$. $\sigma_{\rm fus}$ was taken from Ref. 3, the implied $L_{\rm fus}$ being $\approx 34\hbar$.

The code assumed Fermi gas level density expressions[5] with a parameter $a = A/7.0$, and yrast lines from the rotating diffuse liquid drop model calculation with finite range corrections of Sierk.[9]

The $E1$ γ-ray emission strength function included the giant dipole resonance with shape and position taken from systematics[10,11] and strength determined by the classical energy weighted sum rule.[10] Statistical $E1$ and $M1$ transitions as well as collective stretched $E2$ transitions for $E_\gamma \leq 2$ MeV were included with strengths of $B(E2)=5.5$ W.u., $B(M1)=0.028$ W.u., $B(E2)_{\rm coll}=50$ W.u., and $B(M2)=0.0195$ W.u.[2] The fission competition was also considered.

The validity of our parameters was tested by comparing the predictions of the code with low-energy and angular momentum charged-particle decay data[12] for ^{60}Ni*. A good description of the measured sub-barrier alpha spectra and angular distributions was obtained.

In Fig. 1, we compare the result of our calculation for the alpha spectra, from the deexcitation of ^{60}Ni* (75 MeV), with the corresponding data, reproduced from Ref. 1. The calculated relative spectra were normalized to the measured spectrum at 55° in the laboratory system. In general, we obtain a good description of the peak positions and the slopes of the high-energy tails. There are only small discrepancies in the sub-barrier region of the forward spectra which become more apparent at 35°. A second calculation with the optical-model parameters of McFadden and Satchler[13] for alpha particles produced a result similar to that of Fig. 1, as far as the shapes of the spectra are concerned.

We see from Fig. 1 that the strong deviations claimed by the spherically symmetric calculation of La Rana *et al.* are not observed. In fact, our agreement with the data is very close to their final calculation which fits the spectra. In connection with their proposed modifications, in the spherical calculation, we point out the following:

(1) Their reduction of $L_{\rm fus}$ from $38\hbar$ to $26\hbar$ is unrealistic, since it cannot be supported by published fusion data.[3] As shown below, a decrease in $L_{\rm fus}$ shifts the peak position of the spectra to lower energies. However, $L_{\rm fus}$ cannot be treated as a free parameter.

(2) A reduction of the evaporation barrier is not the only enhancement mechanism of the calculated sub-barrier alpha yields. In this mass region, an equally important role is played by the shapes of the yrast lines. Shifts of the odd-A yrast lines relative to the even-A ones, not included in the structureless liquid drop calculation, also lead to sub-barrier alpha emission enhancements.

The effect of the above two factors is shown in Fig. 2, where different calculated alpha spectra at 55° are plotted in absolute units. The solid line represents the calculated spectrum of Fig. 1. The dashed line shows the result from a similar calculation where $L_{\rm fus}$ was increased from $34\hbar$ to $38\hbar$. The peak position is now shifted to a higher

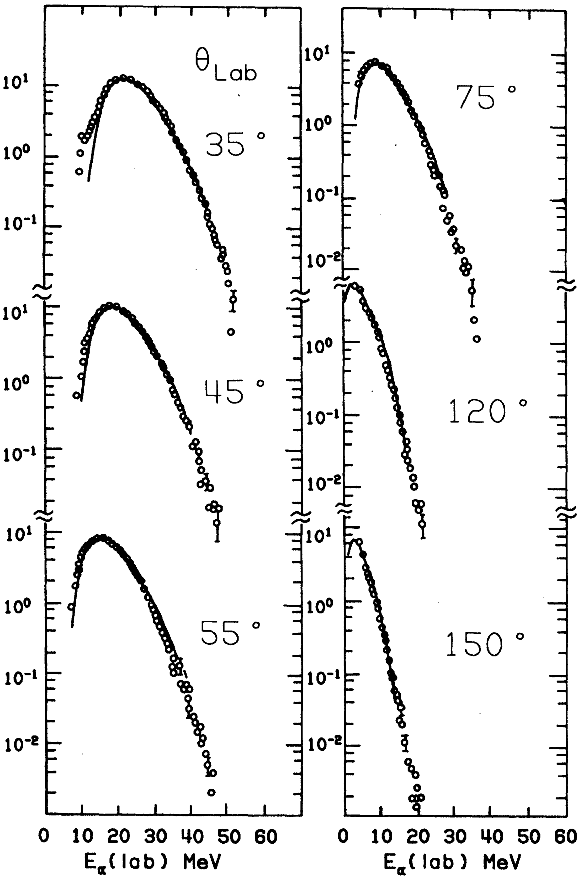

FIG. 1. Laboratory alpha-particle spectra from the deexcitation of ^{60}Ni* (Ref. 1). The solid line describes the result of a statistical-model calculation for spherical nuclei.

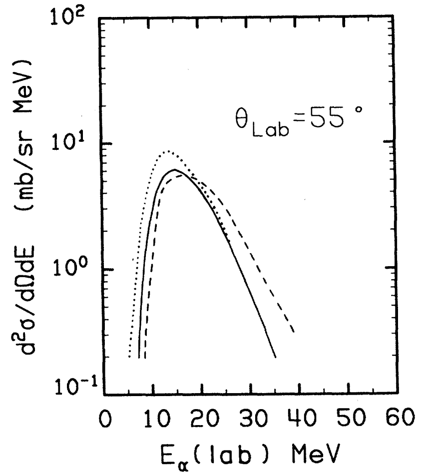

FIG. 2. Calculated alpha-particle spectra at 55° in the laboratory system, corresponding to the parameters discussed in the text.

energy and the spectrum has become harder. The dotted line corresponds to a calculation with $L_{\mathrm{fus}}=34\hbar$ and yrast lines from the combinatorial calculation of Hillman and Grover.[14] This spectrum shows an excess of sub-barrier alphas. It actually overshoots the experimental data at this as well as at the smaller laboratory angles.

Due to our insufficient knowledge of the yrast lines in this mass region, it seems difficult to favor one set over the other. A situation between the two yrast line selections seems to be able to account for the small sub-barrier discrepancies of Fig. 1. In such a case, a complete description of the effect can be given with spherically symmetric parameters. Although a lower evaporation Coulomb barrier also brings better agreement with the sub-barrier data, it seems that such a change is within the limits of uncertainty of the statistical-model parameters. However, even in the case of adopting this as the only physical explanation of the effect, its magnitude is not suggested to be as large as the reported one. It has to be noted that these modifications affect the alpha competition with the other decay modes. The lack of further experimental information of this reaction, such as partial cross sections, prevents us from making any further statements.

On the basis of these observations, we find a high degree of uncertainty in the reported magnitude of the deformation effect. Additional experimental information for this reaction, at the same bombarding energy, would be helpful for a stronger quantitative statement.

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