STATISTICAL-MODEL CALCULATION OF THE SELECTIVE EXCITATION OF HIGH-SPIN STATES IN 24Mg

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STATISTICAL-MODEL CALCULATION OF THE SELECTIVE EXCITATION OF HIGH-SPIN STATES IN ^{24}Mg (*)

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Résumé. — Le peuplement sélectif d'états de haut spin dans le ^{24}Mg par la réaction ^{12}C(^{16}O, α)^{24}Mg, de même que l'absence d'une telle sélectivité dans la réaction ^{14}N(^{14}N, α)^{24}Mg peuvent être expliqués par des calculs faits dans le cadre du modèle statistique de Hauser-Feshbach.

Abstract. — The selective population of high-spin states in ^{24}Mg by ^{12}C(^{16}O, α)^{24}Mg reaction, as well as the lack of such selectivity in the ^{14}N(^{14}N, α)^{24}Mg reaction, can be explained in terms of a Hauser-Feshbach statistical-model calculation.

In the ^{12}C(^{16}O, α)^{24}Mg* reaction, several states in ^{24}Mg at $\sim$ 16 MeV excitation were found to be selectively and strongly populated [1]. In contrast, the ^{14}N(^{14}N, α)^{24}Mg* reaction exhibits an evaporation spectrum which is smooth and without prominent peaks [2]. The differences between the two reactions as well as the strong and selective population of states in the ^{12}C(^{16}O, α)^{24}Mg reaction can readily be explained with the statistical model if the prominent states in ^{24}Mg have high spin, an assumption which indeed has been confirmed for all states whose spins have been determined [3], [4]. The measured excitation functions of the ^{12}C(^{16}O, α)^{24}Mg reaction show strong fluctuations [5] and therefore indicate a strong compound nuclear component in the cross section.

In figure 1, grazing angular momenta $L_{1/2}$ for various reaction channels leading to the compound nucleus ^{28}Si* at 38.2 MeV excitation are plotted versus excitation energy in the reaction channels. The ^{28}Si* energy of 38.2 MeV corresponds to an incident energy of E_{lab} = 50 MeV in the ^{12}C + ^{16}O system. Considerably higher angular momenta can be carried into ^{28}Si via ^{12}C + ^{16}O ($L_{1/2}$ = 16 $\hbar$) than via ^{14}N + ^{14}N ($L_{1/2}$ = 7 $\hbar$). Since there are only very few open channels that can carry away the largest angular momenta brought into the system by ^{12}C + ^{16}O, one will expect CN reactions to feed these channels strongly. In contrast, even the highest spin states excited by the ^{14}N + ^{14}N reaction can α decay to all spin states in ^{24}Mg for $E_x \lesssim 20$ MeV. Therefore one does not expect a selective population of high-spin states in the ^{14}N(^{14}N, α)^{24}Mg reaction.

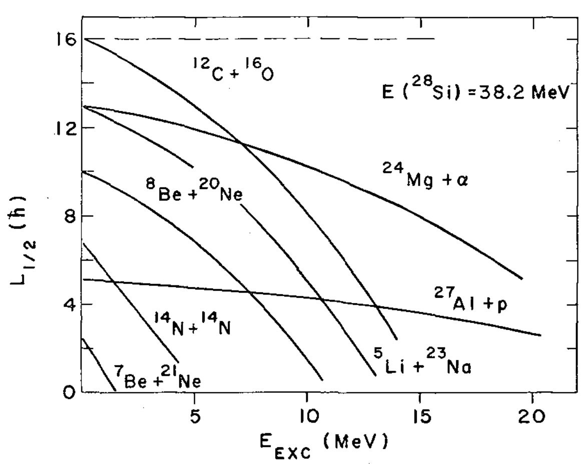

FIG. 1. — Grazing angular momenta $L_{1/2}$ for various reaction channels leading to the compound nucleus ^{28}Si at 38.2 MeV excitation. The abscissa is the excitation energy in the reaction channels.

We have used the Hauser-Feshbach theory to calculate the population of states in ^{24}Mg. The familiar expression for the total cross section is

$$\sigma_{\alpha,\alpha'} = \pi \lambda_\alpha^2 \sum_J \frac{(2J+1)}{(2I+1)(2i+1)} \times \frac{\sum_{SI} T^J_{\alpha SI} \sum_{S'I'} T^J_{\alpha' S' I'}}{\sum_{\alpha'' S'' I''} T^J_{\alpha'' S'' I''}} .$$

We have calculated the denominator $G(J)$ as a discrete sum over all known levels in nine reaction channels plus an integral over the continuum region using a standard level density expression [6]. Optical-model transmission coefficients were calculated at a number of energies and were fitted as a function of energy and l with a 3-parameter Fermi function with energy-dependent parameters. Transmission coefficients generated by this procedure agreed with the original optical model transmission coefficients to $\sim$ 10 % for all important channels. The present calculations neglect direct reactions and assume that the absorption given by the transmission coefficients T_l is due to CN processes only. The calculated cross

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sections are therefore upper limits for the CN contribution.

Figure 2 shows a plot of $G(J)$ along with contributions to $G(J)$ from $^{12}C + {}^{16}O$, $^{24}Mg + \alpha$, and $^{14}N + {}^{14}N$ channels. For large values of J, the denominator is dominated by the $^{12}C + {}^{16}O$ entrance channel and high-spin states of the $^{24}Mg + \alpha$ channel and is very sensitive to the number and excitation energy of high-spin states in ^{24}Mg. Uncertainties in the level-density parameters make some quantitative differences in the results obtained (which are strongly dependent on the behavior at high J), but the qualitative results for $^{12}C + {}^{16}O$ and $^{14}N + {}^{14}N$ reactions remain unchanged.

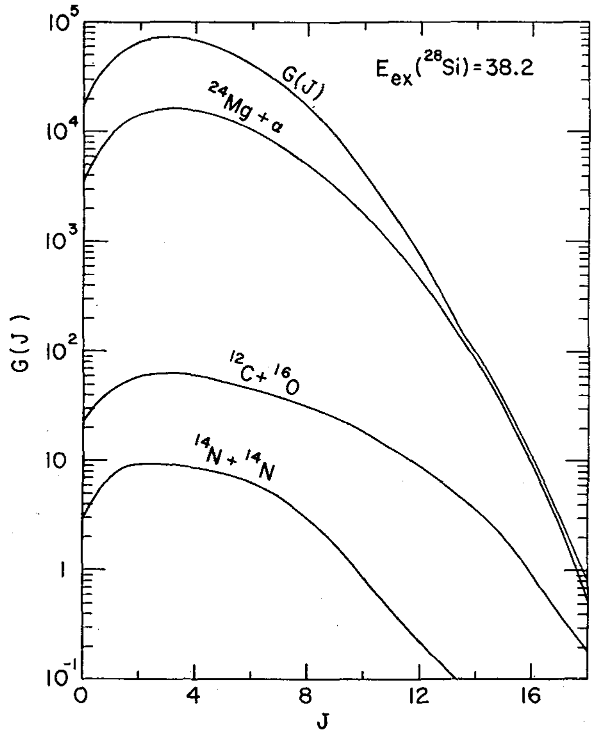

FIG. 2. — « Number of open channels » $G(J)$ for the decay of the compound nucleus ^{28}Si at 38.2 MeV for different compound-nucleus spins J. The total contributions from the $^{12}C + {}^{16}O$, $^{14}N + {}^{14}N$, and $^{24}Mg + \alpha$ channels to $G(J)$ are also shown.

Figure 3 is a plot of cross sections to various I^{π} states at 12-18 MeV excitation energy in ^{24}Mg The left-hand ordinate is total cross section and (if a $1/\sin\theta$ angular distribution is assumed) the right-hand ordinate corresponds to differential cross section at $\theta_{c.m.} = 12°$. Absolute cross sections are consistent with experiment. As can be seen from this figure, states of I_f = 6-10 are very strongly populated relative to states of lower spin in the $^{12}C + {}^{16}O$ reaction, in marked contrast to the $^{14}N + {}^{14}N$ results.

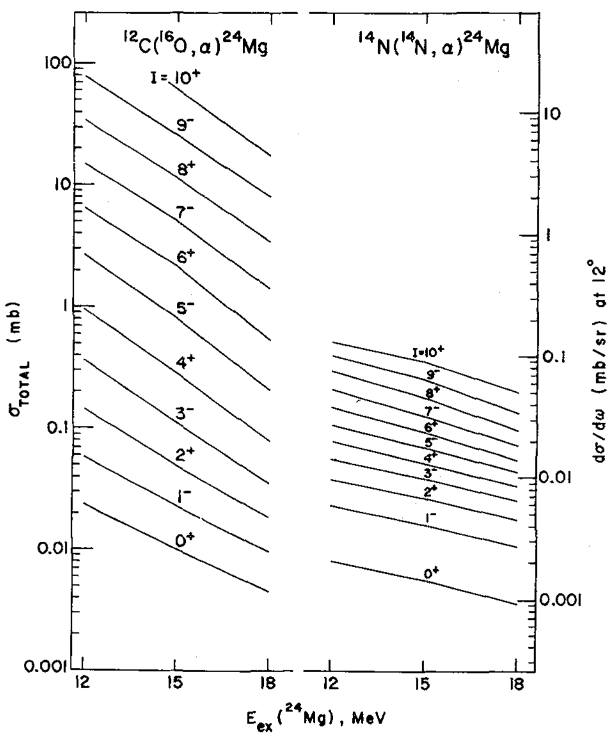

FIG. 3. — Cross sections for the population of natural-parity states in ^{24}Mg for excitation energies between 12 and 18 MeV.

Using σ (I = 0-5) from figure 3 as a background and employing level-density parameters to find the number of levels in a 16-17 MeV region of excitation in ^{24}Mg leads to estimated peak-to-background ratios whose values for I = 10, 9, 8, 7 and 6 are respectively, 11, 6, 3, 2 and 1 for $^{12}C(^{16}O, \alpha)^{24}Mg$ and 0.38, 0.26, 0.19, 0.14 and 0.1 for $^{14}N(^{14}N, \alpha)^{24}Mg$, in qualitative agreement with experimentally observed spectra.

References

[1] MIDDLETON (R.), GARRETT (J. D.) and FORTUNE (H. T.), *Phys. Rev. Letters*, 1970, **24**, 1436.

[2] MIDDLETON (R.), GARRETT (J. D.) and FORTUNE (H. T.), *Bull. Am. Phys. Soc.*, 1971, **16**, 37 and preprint.

[3] GOBBI (A.) *et al.*, *Phys. Rev. Letters*, 1971, **26**, 396.

[4] BALAMUTH (D. P.), HOLDEN (J. E.), NOE (J. W.) and ZURMÜHLE (R. W.), *Phys. Rev. Letters*, 1971, **26**, 1271.

[5] GREENWOOD (L. R.), BRAID (T. H.), KATORI (K.), STOLTZFUS (J. C.) and SIEMSSEN (R. H.), *Bull. Am. Phys. Soc.*, 1971, **16**, 37 and contribution to this Conference.

[6] FACCHINI (U.), SAETTA-MENICHELLA (E.), *Energia Nucleare*, 1968, **15**, 54.