# Cross section fluctuations in alpha particle scattering by 24Mg, 26Mg and 28Si

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## SUMMARY

The aim of the present investigation is to evaluate average properties of highly excited compound nucleus states from an analysis of fluctuations observed in nuclear reaction cross sections as a function of energy. Studied are the elastic and inelastic scattering of alpha particles by $^{24}Mg$, $^{26}Mg$ and $^{28}Si$ at bombarding energies ranging from about 18 to 28 MeV. From the cross section fluctuations it is possible to determine: (1) the average total level width $\Gamma$ of compound nucleus levels as a function of excitation energy; (2) the relative contribution of direct interaction processes, $y_D$, and compound nucleus formation, $1-y_D$, to the cross section; (3) the effective number of reaction channels, $N_{eff}$. From the value of $\Gamma$ one may derive the level density at high excitation energies.

In the introductory chapter some aspects of the present investigation are mentioned. Attention is drawn to other reaction studies leading to the same compound nuclei $^{28}Si$, $^{30}Si$ and $^{32}S$ at comparable excitation energies.

Chapter two deals with the theory of cross section fluctuations developed by Ericson, and by Brink and Stephen. The assumptions underlying the theory are discussed and the relations connecting theory with experiment are given. Some relevant quantities as autocorrelation and cross correlation functions, distribution functions and effective number of reaction channels are discussed.

The methods to obtain the true fluctuation parameters from experimental excitation functions are treated in chapter three. The finite length of the energy interval over which measurements can be made in practice, the experimental energy resolution, and the distance between the experimental points of an excitation function lead to apparent values of the fluctuation parameters which differ considerably from the true ones. The corrections which are necessary to obtain the true values are discussed in detail. Many of the correc-

tion formulas given in this chapter are obtained by studying each effect in particular by means of computer generated excitation functions.

In chapter three also a method is given to perform a fluctuation analysis when effects of non-statistical origin are present in the excitation functions. For that purpose a new "reduced" excitation function is constructed by dividing every experimental point of the original excitation function by the average value of neighbouring points. By choosing an appropriate value of the averaging interval reduced excitation functions are obtained which yield undistorted autocorrelation and distribution functions, leading to unambiguous though incorrect values of $\Gamma$ and $y_D$. It can be shown, however, in which way the parameters obtained from the analysis of reduced excitation functions have to be corrected in order to find the true values. The correction factors are derived analytically and tested by the synthetic excitation functions.

In chapter four we describe the experimental set up. Some characteristics of the Philips AVF cyclotron, the accelerator which provided the alpha particle beam, are given. The method used to determine the energy of the particle beam is outlined. The scattering chamber, provided with four surface barrier detectors, and the electronic equipment used in our experiments is described.

The actual analysis of experimental data is given in chapter five. The coherence width $\Gamma$ is obtained with the autocorrelation method, and also from the number of maxima present in excitation functions. The amount of direct interaction $y_D$ is obtained from the distribution of the cross sections. The value of the autocorrelation function at zero argument and the value of $y_D$ yield the experimental value of the number of reaction channels. This quantity is also calculated theoretically with the Hauser-Feshbach formalism. In section 5.5 a method is outlined to detect in excitation functions structures of larger width than those due to purely compound nuclear processes; the method is based on some statistical properties of cross correlation coefficients.

Chapter six contains the discussion of results. The experimental $\Gamma$-values, which ranged from 81 to 116 keV for the compound nucleus $^{28}Si$, from 83 to 94 keV for $^{30}Si$ and from 51 to 69 keV for $^{32}S$ at excitation energies between about 23 and 33 MeV are compared with theory. The rather small increase of the experimental $\Gamma$-values with energy can be explained rather well when the level density is calculated according to the back shifted Fermi gas model, and a nuclear moment of inertia is introduced, which is energy dependent and ranges from 50% of the rigid body value $\tilde{\mathcal{J}}_r$ at low energies to $\mathcal{J}_r$ at high energies

It is found that in the energy region studied the direct interaction mechanism governs the elastic alpha particle scattering and the inelastic scattering to the lowest excited $2^+$ and $0^+$ states of $^{24}Mg$, $^{26}Mg$ and $^{28}Si$. Only the scattering to the $3^+$ level at 5.22 MeV and the $4^+$ level at 6.00 MeV in $^{24}Mg$, and to the $3^+$ level at 6.27 MeV and the $4^+$ level at 4.61 MeV in $^{28}Si$ are exceptions: here the scattering proceeds almost entirely by compound nuclear processes.

The experimental values of the effective number of reaction channels agree well with theoretical calculations of $N_{eff}$, giving confidence in the consistency of the analyses.

In the last section of this chapter we present evidence for the presence of intermediate structures in the excitation functions for the $^{24}Mg+\alpha$ and $^{28}Si+\alpha$ reactions, using the method outlined in chapter five. These structures have a width of about 400 keV and are found in the bombarding energy region between 20 and 23 MeV.