UNIVERSIDADE DE SÃO PAULO

**INSTITUTO DE FÍSICA**
**CAIXA POSTAL 20516**
**01498 - SÃO PAULO - SP**
**BRASIL**



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# STUDY OF THE NUCLEAR FUSION OF $^{16}O + ^{64,66}Zn$ SYSTEMS AND ELASTIC SCATTERING IN $^{16}O + ^{64,68}Zn$

C. Tenreiro, J.C. Acquadro, P.A.B. Freitas
and R. Liguori Neto

Instituto de Física, Universidade de São Paulo

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# STUDY OF THE NUCLEAR FUSION OF $^{16}O + ^{64,66}Zn$ SYSTEMS AND ELASTIC SCATTERING IN $^{16}O + ^{64,68}Zn$

C. Tenreiro, J.C. Acquadro, P.A.B. Freitas and R. Liguori Neto
Instituto de Física, Deptº de Física Nuclear, Universidade de São Paulo
C.P. 20516, 01498 - São Paulo, SP

## Introduction

An experimental study of $^{16}O + ^{64,66}Zn$ reactions was made, centered in measurements of nuclear fusion from sub-coulomb barrier ($V_b$) energies up to near twice the $V_b$. Further, elastic scattering angular distributions were obtained for the $^{16}O + ^{64,68}Zn$ systems for energies near and above the $V_b$.

The results have shown the following interesting features: An enhancement of the nuclear fusion cross sections, for energies bellow the $V_b$, when compared to the predictions of a single one-dimensional barrier penetration model (BPM) for both the systems studied; also an isotopic dependence of the nuclear fusion excitation function was observed, when the geometrical influences of the systems are removed, for the same energy region. (This has been observed in some systems[1] and they are completely absent in others[2]). Additional fusion data taken with the time-of-flight technique[3] have shown the presence of fission-like residues for the $^{16}O + ^{64}Zn$ system in energies above ≈1.2 $V_b$.

From the elastic scattering data analysis we have found an interesting behaviour for relatively backward angles ($\theta_{LAB}$>120°) in energies around the $V_b$ for the $^{16}O + ^{64}Zn$ system. There is an enhancement of the elastic cross section for this angular region and this cannot be explained by the application of a single optical model analysis[4].

## Experiments and Analysis

The nuclear fusion and elastic scattering data were taken at the Pelletron Accelerator Laboratory of University of São Paulo using the 30°A and 15°B beam lines in conjunction with the Laboratory facilities for $\gamma$-ray, particle detection and data analysis. The fusion cross section measurements were obtained from the detection of $\gamma$-rays emitted from the Compound Nucleus (CN) evaporation residues and calculated adding their contribution to the cross section. This process requires a careful analysis of activation and decay spectra taken in and out of beam measurements for each energy of the excitation functions (a detailed explanation about the experimental method is found in reference[3]).

The nuclear fusion excitation functions were measured from sub-coulomb barrier energies (≈0.8 $V_b$) up to 1.7 times the $V_b$ for the $^{16}O + ^{64,66}Zn$ systems.

Furthermore angular distributions for the elastic scattering of $^{16}O + ^{64,68}Zn$ were measured from near forward angles ($\theta_{LAB}$≈20°) up to backward angles ($\theta_{LAB}$≈170°) and for energies near and above the $V_b$. For these measurements, an array of four surface barrier Si was used with two Si detectors for monitoring the beam (placed at ±25° to the beamline). For more details see reference (3). From the fusion data taken for energies above the $V_b$ some characteristic parameters of the systems such as the radius and height of the coulomb barrier (see table 1), could be calculated, fitting the data with an BPM and the proximity potential[5] as the nuclear part of interaction. Figures (1-2) show the results of the fit in a typical $\sigma_{FUS}$ vs. $1/E_{CM}$ plot. The sub-coulomb enhancement of fusion data of $^{16}O + ^{64}Zn$ can be explained taking into account the influence on the fusion of the deformation of $^{64}Zn$ by the application of the Wong model with deformation[6]; however, for the data with $^{66}Zn$ as target, values of deformation parameters larger than the measured value are needed to fit the data, showing the presence of other open channels coupled to the fusion channel[7]. Table 1 shows the values obtained including the value of a small variation $\Delta R$ in the nuclear radii in order to fit the above barrier fusion data with an BPM. These parameters are in good agreement with the values obtained for other systems compiled in reference (8).

On the other hand, we can show the presence of a more complex situation in sub-barrier energies, when the $^{66}Zn$ target is used viewing the shifting value ΔB (Table 1), along the energy axis, to improve the agreement between the one-dimensional BPM prediction and the data, this parameter can be reproduced for $^{16}O + {}^{64}Zn$ using a liquid-drop model description of heavy ion fusion at sub-barrier energies[9], which consider a neck formation between the interacting ions; but it cannot be reproduced for the system with $^{66}Zn$ as target, in this case a larger value of ΔB than the predicted value is needed, indicating a more complex situation in which several degrees of freedom must be considered. Measurements of cross sections for other reaction channels for these systems and for energies near the Coulomb barrier are needed to understand the complete picture including the influence of nuclear structure on the process. For this purpose measurements of reaction cross sections for $^{16}O + {}^{68}Zn$ and $^{18}O + {}^{64,66,68}Zn$ are in progress[10]. The elastic scattering analysis for the systems referred here are in reference (3) including all the systems studied, giving a more global picture of the behaviours observed.

The total reaction cross sections were extracted from these measurements with an optical model analysis of data (using the PTOLEMY Code) and the semiclassical Fresnel model. A very good agreement between the two values was obtained for energies above the $V_b$, when the grazing angular momentum is greater than 10[4,7] as expected[11]

TABLE 1— CHARACTERISTIC PARAMETERS FOR THE $^{16}O$+ Zn REACTIONS (PRT-PROXIMITY POTENTIAL AND BPM)

| SYSTEM | Vb (MeV) | Rb (fm) | ħω (MeV) | $\beta_2^{WONG}$ | $\beta_2^{exp}$ | $\Delta B^{fit}$ (MeV) | $\Delta B^{model}$ (MeV) | ΔR (fm) |
|---|---|---|---|---|---|---|---|---|
| $^{16}O + {}^{64}Zn$<br>PRT | 32.7 ± 3.1<br>32.02 | 10.3 ± 0.3<br>9.98 | 3.48 ± 0.21<br>3.93 | 0.223±0.014 | 0.250 | 1.5±0.2 | 1.30 | 0.247 |
| $^{16}O + {}^{66}Zn$<br>PRT | 34.5 ± 3.0<br>33.42 | 9.6 ± 0.3<br>9.53 | 4.15 ± 0.33<br>3.89 | 0.337±0.006 | 0.227 | < 2.5 | 1.26 | 0.156 |

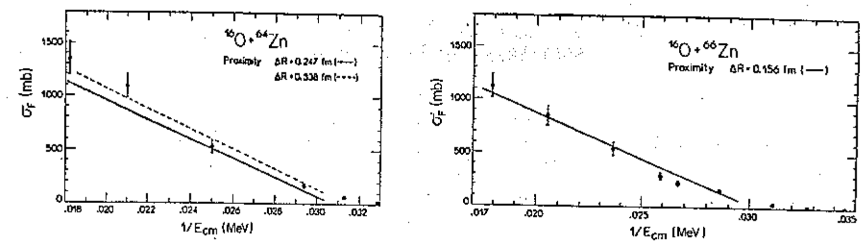


Figure 1-2

This figures shown the data fit with BPM using a smal variation ΔR of nuclear radius as variable parameter to improve the data fit.


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