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ELASTIC SCATTERING INDUCED BY ^{16}O ON ^{208}Pb*

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ABSTRACT

Elastic scattering cross sections have been measured for ^{16}O on ^{208}Pb targets at incident energies of 80, 83, 88, 90, 96, and 102 MeV. These data along with existing elastic scattering measurements for this system at 94, 104, 129.5, 140, 192, and 216.6 MeV have been analyzed in terms of the optical model. For incident energies near the Coulomb barrier, a significant difference is observed between the grazing angular momentum and the total reaction cross sections predicted from the optical model and such values obtained from the semiclassical "quarter-point" prescription. Measured quasielastic and fission cross sections exceed the "quarter-point" total reaction cross section as much as 35% at the lowest incident energies in this analysis indicating that it is imperative that the "quarter-point" method not be used to predict grazing angular momenta and reaction cross sections at incident energies near the Coulomb barrier. The incidence energy dependence of the radial region in which the real nuclear potential is determined by the elastic data also has been studied.

* Work performed under the auspices of E.R.D.A.

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Oxygen-16 plus ^{208}Pb is an ideal system for the study of elastic scattering. The absence of low-lying excited states in both the projectile and target and the Q values for the various transfer reactions allow the elastic scattering to be resolved experimentally from other processes. The present contribution presents new ^{16}O + ^{208}Pb elastic data at incident energies of 80, 83, 88, 90, 96, and 102 MeV. Existing data[1-3] at 94, 104, 129.5, 140, 192, and 216.6 MeV also have been reanalyzed and the resulting systematics are discussed.

The data were obtained using ^{16}O beams from the Brookhaven National Laboratory three-stage tandem accelerator facility. The elastically scattered ^{16}O ions were identified using standard silicon surface barrier detector telescope techniques[4]. The angular distributions of the elastic scattering data are shown in fig.1.

The heavy-ion version of the optical model search code ABACUS[5] and HIGENOA[6] has been used to analyze these data in a systematic way. In the analysis Woods-Saxon potentials with identical real and imaginary geometry were used. In the automatic searches the radius and imaginary well depth were varied for a fixed real potential of V_0= 100 MeV and various diffusivities ($0.45 \leq a \leq 0.55$ fm). The best fit potentials, for a=0.50 fm,

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are tabulated in Table 1, and the resulting predicted cross sections are shown as the full drawn curves with the experimental data in Fig.1. The angular dependence of the higher energy elastic data not shown in Fig.1 is reproduced essentially as well as it was in the original references.

Table 1. Parameters from Optical-Model and "Quarter-Point" Analyses of $^{16}O + ^{208}Pb$ Elastic Data

	Optical-Model						Quarter-Point		
E_{lab} (MeV)	V (MeV)	W (MeV)	r_o (fm)	a (fm)	ℓ_g [a] ($\hbar$)	σ_R (mb)	$\theta_{1/4}$ (deg)	ℓ_g ($\hbar$)	σ_R (mb)
80	100	21.8	1.249	0.50	9.8	113	b)	b)	b)
83	100	37.9	1.244	0.50	20.3	287	139	16.5	174
88	100	64.6	1.232	0.50	30.4	562	115	27.5	440
90	100	66.9	1.233	0.50	33.8	668	107	31.7	565
94[c]	100	81.8	1.232	0.50	39.9	876	96	37.9	763
96	100	66.5	1.234	0.50	41.9	939	92	40.2	840
102	100	71.4	1.227	0.50	48.1	1156	82	46.5	1053
104[d]	100	72.4	1.235	0.50	50.9	1268	78	49.5	1166
129.5[e]	100	46.2	1.255	0.50	72.0	2000	52.9	72.5	1985
140[d]	100	48.6	1.221	0.50	75.9	2058	48.5	77.0	2070
192[e]	100	39.3	1.237	0.50	103.8	2781	31.4	105.6	2815
216.6[d]	100	47.1	1.216	0.50	112.7	2902	27.4	114.6	2937

a) Angular momentum for which the transmission coefficient $T_\ell = 1/2$.
b) Elastic data do not fall to 0.25 σ_{Ruth}.
c) Data from ref.3.
d) Data from ref.1.
e) Data from ref.2.

The grazing angular momentum, ℓ_g, and the total reaction cross section, σ_R, also have been calculated from a semiclassical "quarter-point" analysis:

$$\ell_g + 1/2 = \eta \cot(\theta_{1/4}/2)$$

where $\eta = Z_1 Z_2 e^2/\hbar v$ is the Coulomb parameter and $\theta_{1/4}$ is the center-of-mass angle at which the experimental elastic cross section falls to 1/4 of the Rutherford value.

$$\sigma_R = \pi \lambda^2 (\ell_g + 1)^2$$

The values for ℓ_g and σ_R obtained from such a semiclassical prescription are compared in table 1 with similar values obtained from the optical model calculations. At the lowest incident energies, which are near the Coulomb barrier, the grazing angular momentum, ℓ_g, obtained from the optical model analysis of the Pb data is nearly four units larger than the corresponding value from the "quarter-point" analysis. This discrepancy decreases at higher incident energies; however, the value from the optical model analysis remains consistently larger than that of the "quarter-point" formula up to an incident energy of 129 MeV. Such a variation in the grazing angular momentum also is reflected in the total reaction cross sections predicted using these two prescriptions. Indeed the sum of the measured fission and quasielastic cross sections for this system exceeds the "quarter-point" total reaction cross section by as much as 35% at incident energies near the Coulomb barrier[4].

Two potentials of Woods-Saxon geometry with constant well depths and varying diffusivities can only have identical values in the exponential region at a single radius. Therefore, the radial region in which the potentials are determined by the elastic scattering data may be studied by fitting the same data with Woods-Saxon potentials of different diffusivity[7]. Sensitive radii, defined as the radii at which the various real nuclear potentials which fit the elastic data have identical values, are shown in Fig.2 as a function of the incident energy. Also shown for comparison in this figure are strong absorption radii obtained from $\theta_{1/4}$:

$$kR = \eta(1 + \csc\frac{\theta_{1/4}}{2}).$$

The sensitive radii increase with increasing incident energy up to 90-95 MeV. At higher bombarding energies, however, the value of such sensitive radii no longer increases.

The sharp decrease in the radius sensitive to the optical model parameters as the incident energy approaches the Coulomb barrier from above is not understood. Elastic scattering usually is thought to determine the height and radius of an interaction barrier that is the sum of the potentials associated with the Coulomb and nuclear forces and angular momentum. For increasing energy and angular momentum such a barrier position will move toward smaller radii!

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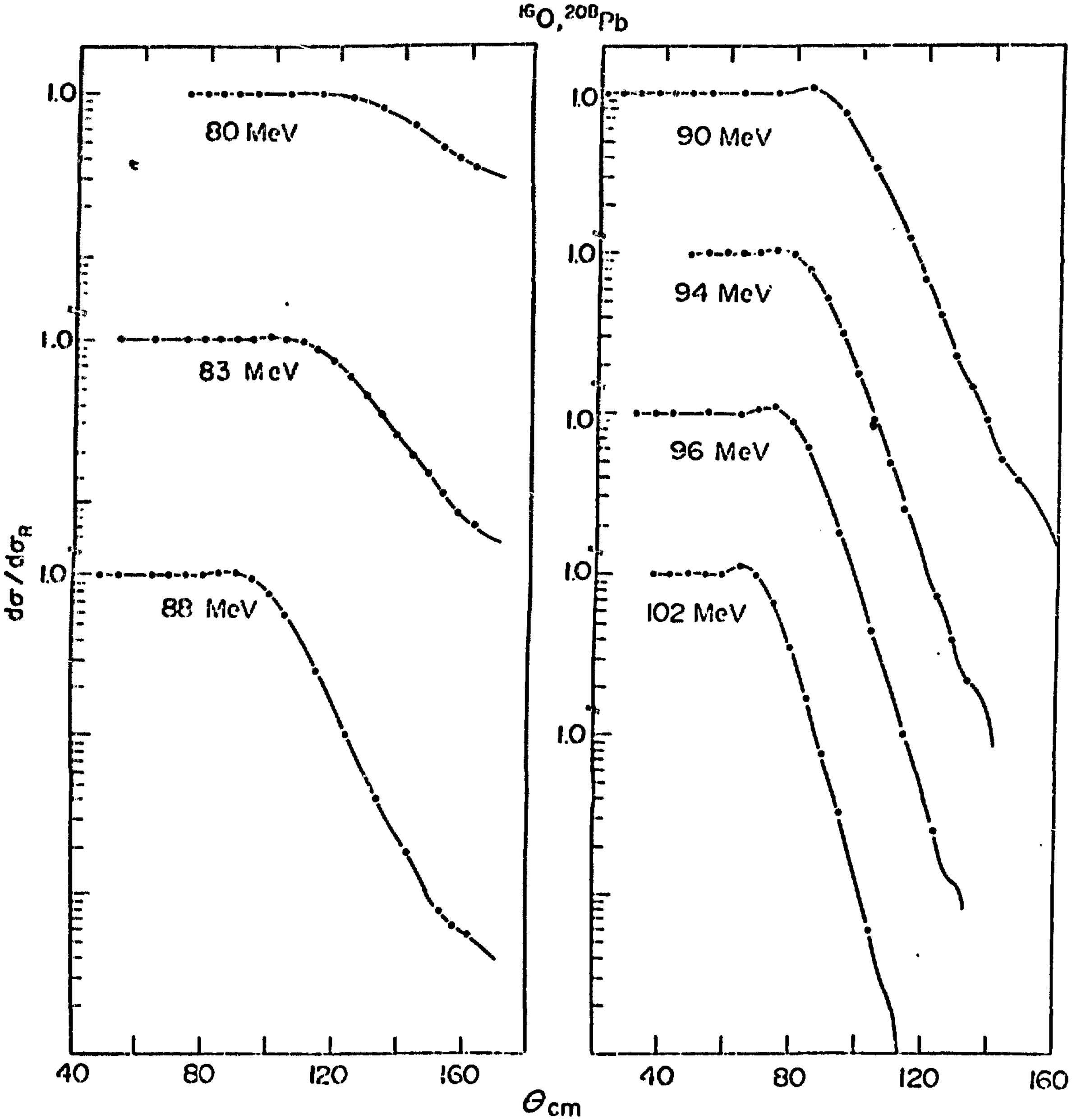
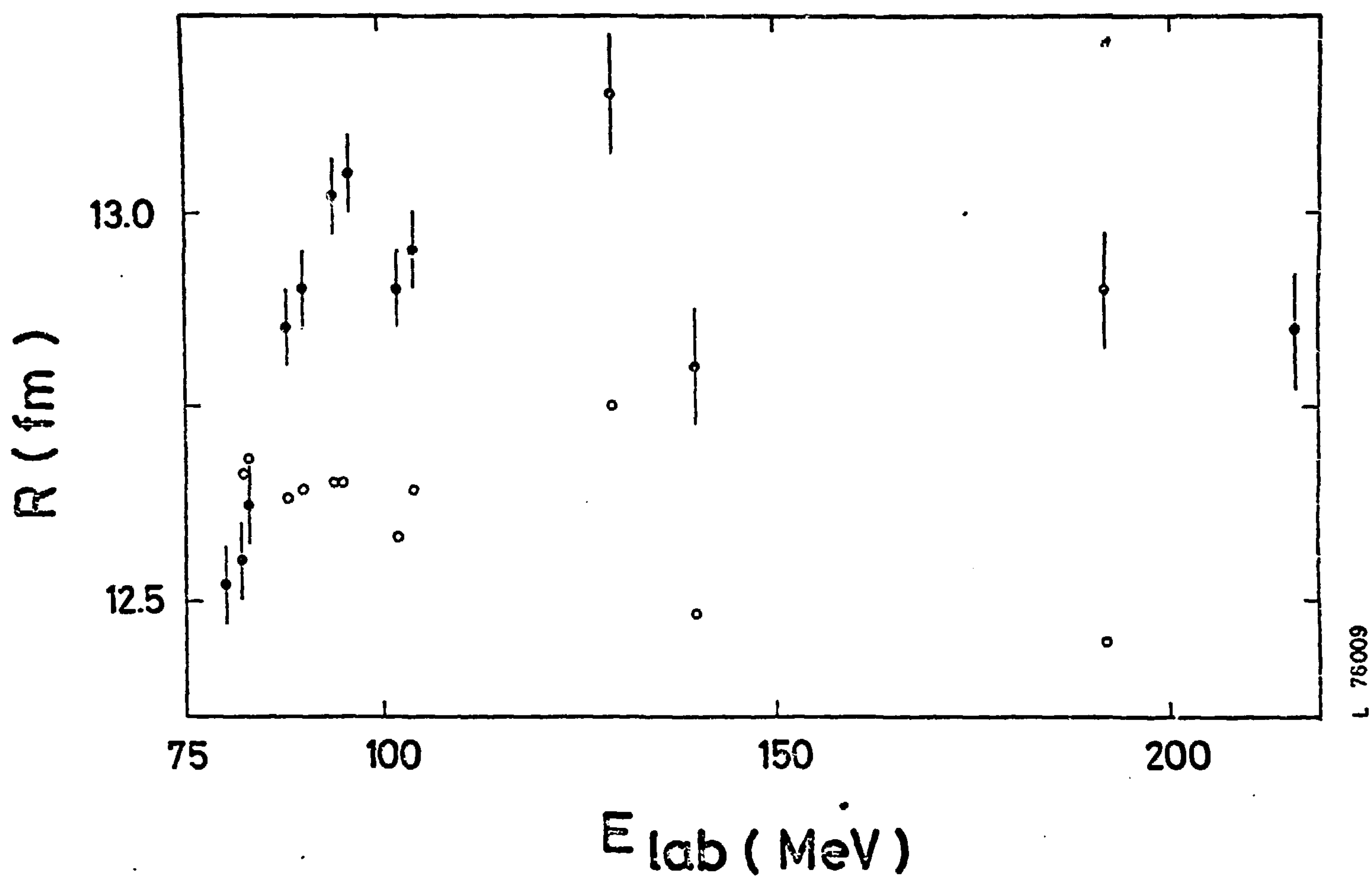
FIGURE CAPTIONS

Fig.1. Angular distributions of ^{16}O elastically scattered from a ^{208}Pb target. The 94 MeV data are from ref.3. The full drawn curves are optical model calculations based on the parameters given in Table 1.

Fig.2. Optical model sensitive radius, solid points, (see text) shown as a function of the incident energy. Also shown for comparison (open points) are strong absorption radii determined from a "quarter point" analysis.


16O, 208Pb
dσ / dσR
1.0
80 MeV
83 MeV
88 MeV
90 MeV
94 MeV
96 MeV
102 MeV
40
80
120
160
θcm


R (fm)
13.0
12.5
75
100
150
200
E lab (MeV)
L 76009