Elastic Scattering of Nitrogen by Nitrogen*

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The differential cross section for the elastic scattering of nitrogen by nitrogen is calculated approximately by using a classical model which has been found previously to account for the elastic scattering of alpha particles by heavy nuclei. The effective mean free path in the collision process is found to be 15 to 35 times smaller than the interaction radius (twice the radius of a single nitrogen nucleus), indicating an extremely strong interaction when two "chunks" of nuclear matter collide.

I. INTRODUCTION

To explain the observed angular distributions of alpha particles elastically scattered by heavy nuclei, a simple classical model was proposed.[1] It seems to be worthwhile to record briefly to what extent this model can also account for the angular distribution of nitrogen elastically scattered by nitrogen which has been measured recently.[2]

II. THEORY

Except for the modification of the formulas to take into consideration the identity of the incident and target nuclei and the obvious necessity of distinguishing between the center-of-mass and laboratory frames of reference, the approach is exactly the same as that used for alpha-particle scattering.[1] The angular distribution in the laboratory system is found to be

$$\frac{d\sigma_{\mathrm{el}}}{d\Omega}(\theta)=\left(\frac{Z^2e^2}{2E}\right)^2\{\csc^4\theta T[\xi(\theta),\delta] +\sec^4\theta T[\xi(\tfrac{1}{2}\pi-\theta),\,\delta]\}4\cos\theta, \quad (1)$$

where θ is the laboratory scattering angle, E is the energy of the incident nitrogen nucleus in the laboratory system, δ is the ratio of the diffuseness distance d to the interaction radius R, and the ratio ξ of the apsidal distance D to the interaction radius R is given as a function of energy and angle by

$$\xi(\theta)=\frac{Z^2e^2}{RE}(1+\csc\theta). \quad (2)$$

The transmission coefficient $T(\xi,\delta)$ is defined as

$$T(\xi,\delta)=\exp[-(2R/l_0)h(\xi,\delta)], \quad (3)$$

with plots of $h(\xi,\delta)$ given in reference 1. The interaction radius R is taken to be: $R=2r_0A^{\frac{1}{3}}$. The charge and mass parameters appropriate to nitrogen are $Z=7$ and $A=14$. The radius and diffuseness parameters were assumed to be $r_0=1.3\times10^{-13}$ cm and $\delta=0.25$, the latter corresponding to an edge diffuseness distance of about 0.4×10^{-13} cm for each nitrogen nucleus.

III. RESULTS AND DISCUSSION

Figures 1(a)–1(d) show the available data[2] and calculated results. The energies range from 15.0 to 21.7 Mev and the angles from 10 to 55 degrees. Calculated curves are labeled by various values of R/l_0, except for the 15-Mev data in which case there is essentially no collision (the transmission factor T remains unity for all angles) and the calculated curve is unaffected by varying R/l_0. As the energy is increased, the amount of mutual penetration of the nitrogen nuclei increases, and changing R/l_0 has more effect. This is most evident from the plot for $E=21.7$ Mev.

Since the model is a completely classical one, it is perhaps more valid in discussing the amount of absorption needed to fit the data to avoid basing conclusions on regions of the data where wave-mechanical effects seem to be strongly indicated. The oscillations observed in the 15.0-, 17.7-, and 19.2-Mev data are accounted for by the interference term in the Mott formula.[2] In the 21.7-Mev data, the flattening in the vicinity of 45 degrees is also a diffraction effect and is explained by Blair's model.[2,3] For the latter reason, there does not seem to be too much sense in judging the model discussed here by the agreement at the minimum of the calculated curves; the region of drop from the $R/l_0=0$ curve seems to be a more appropriate region to use to determine the "best" value of R/l_0. In any event, it is safe to conclude that the ratio R/l_0 lies somewhere between 15 and 35. This conclusion underlines the extremely strong nature of the interaction which takes place when two "chunks" of nuclear matter collide.

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[1] C. E. Porter, Phys. Rev. **99**, 1400 (1955).
[2] H. L. Reynolds and A. Zucker, Phys. Rev. **102**, 1378 (1956).
[3] J. S. Blair, Phys. Rev. **95**, 1218 (1954).

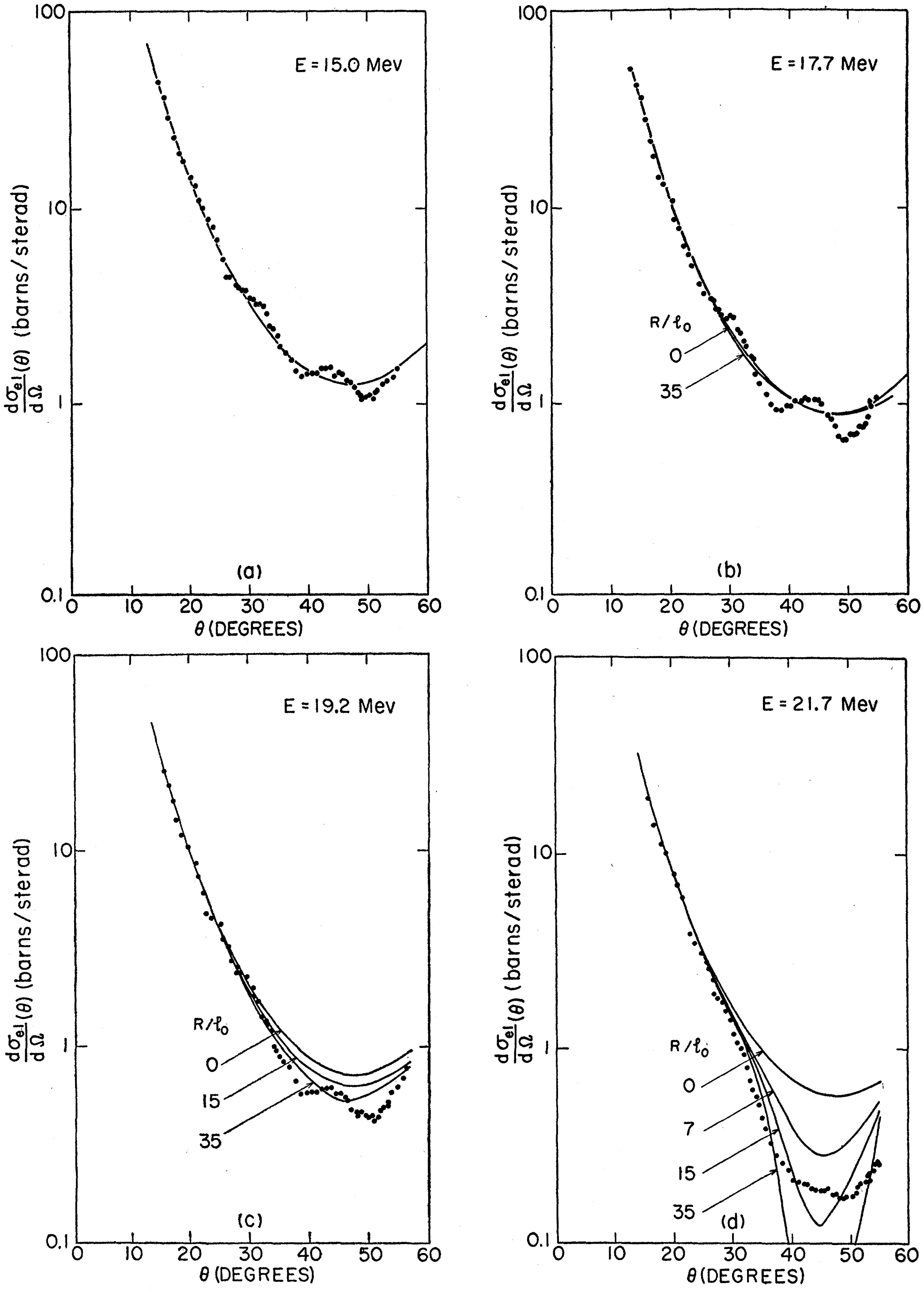

FIG. 1. Plots of the angular distribution of the elastic scattering of nitrogen by nitrogen ($Z=7$, $A=14$). The points are experimental data from reference 2. Calculated curves based on Eq. (1) are shown for various values of E and R/l_0: (*a*) for $E=15.0$ Mev the calculated curve is not sensitive to R/l_0; (*b*) for $E=17.7$ Mev, $R/l_0=0$, 35; (*c*) for $E=19.2$ Mev, $R/l_0=0$, 15, 35; (*d*) for $E=21.7$ Mev, $R/l_0=0$, 7, 15, 35. In all cases, $\delta=0.25$ and $R=2(1.3\times10^{-13})A^{\frac{1}{3}}$ cm. Figure 1(d) contains a curve for $R/l_0=35$. The minimum value not shown is 0.015 barns/sterad at 45 degrees.