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SIGMA CENTER

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INTRODUCTION

We present here some of the results obtained in the course of a study of elastic and inelastic scattering of neutrons by heavy elements in the MeV region. The theoretical bases for this investigation, together with conclusions relating to nuclear structure will be dealt with more fully in a forthcoming paper[1]; we give here only a brief summary of these questions and present the results of our calculations.

The isotopes chosen represent a variety of deformed[2] and spherical nuclei in the heavy element region; the calculational approach used a spherical optical potential. Thus, a reasonably consistent fit to the experimental data by this method would indicate that there exist spherical parameters equivalent to the deformed cases. Simplifying assumptions have been made with respect to energy variation of the parameters, etc.

We started by considering the total and differential elastic cross section data for Ta^{181}, W^{184}, Au^{197}, Pb^{208}, Bi^{209}, Th^{232}, and U^{238} as given in BNL-325[3], BNL-400[4] and more recent data[5-8], in the region from 0.1 to 2.0-5.0 MeV, depending on the element. We then obtained a best fit to the experimental data (except where noted this fit was to the total cross section and differential elastic cross section jointly) using a spherical optical potential whose real part was of the Woods-Saxon[9] form and imaginary part of the gaussian form.[10] To the real part a spin-orbit term of the Thomas form was added. The resulting potential is thus:

$$V(r) = \frac{-VRE}{1+\exp(\frac{r-R}{a})} - VIM\ \exp[-(\frac{r-R}{b})^2] - VSR(\frac{h}{\mu_\pi c})^2\ \frac{1}{r}|\frac{df}{dr}|\vec{\ell}\cdot\vec{\sigma}$$

where

$$f = \frac{1}{1+\exp(\frac{r-R}{a})}$$

$$R = R_o\ A^{1/3} \qquad\qquad A = \text{mass of isotope}$$

and VRE, VIM, VSR are assumed to be energy-independent. Of the six parameters which define the potential, consideration was given to all but b. VIM and b are intimately related and thus, for a wide range of b similar changes may be effected by changing VIM. Since the optical model does not include compound elastic processes in its "elastic" scattering, the inelastic procedure described below was used to obtain the compound elastic contributions to elastic scattering. The total elastic scattering was used in obtaining fits to the data.

Then, using the parameters thus determined, and the level schemes of Nuclear Data Tables[11], the Hauser-Feshbach[12] theory, suitably modified to take into account transmission coefficients which are functions of j as well as ℓ[13], the inelastic scattering cross sections, in the energy ranges where the level schemes are known, were calculated. For each of the possible inelastic exit channels, the same parameters as for the entrance (elastic) channel were used. In general, the features of the inelastic scattering cross sections as a function of energy are well reproduced.

For each of the isotopes that follow, the source(s) of total and differential cross section data are given together with the parameters that best fit these data. The fits were obtained by first scanning the parameter space to find promising regions, and then searching to find the best fit. This procedure is essential since in many cases, particularly where the data is not smooth, a search beginning at an arbitrary point leads only to a local minimum in χ^2.

Then, using the level schemes noted, inelastic scattering cross sections were calculated. Where the total and differential elastic data could be fit with a variety of parameters in the same neighborhood in the parameter space (non-sharp χ^2 minimum), the inelastic cross sections in this region were also investigated. The results given represent calculated values which most closely fit the experimental data and whose parameters are within the region of approximately best fit for total and differential elastic cross sections.

All calculations were performed with the ABACUS-2 optical model computer program[14], using the IBM-7094 at Brookhaven National Laboratory.