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COHERENT THEORETICAL INTERPRETATION OF NUCLEON INTERACTIONS WITH ^{197}Au

J.P. Delaroche, J. Jary

Service de Physique Nucléaire - Centre d'Etudes de Bruyères-le-Châtel - B.P. n° 561

92542 MONTROUGE CEDEX - France

A parametrisation of the nucleon-^{197}Au optical potential is given. Predictions of various cross-sections are discussed between 10 keV and 30 MeV.

1. Introduction

In this study, the spherical optical potential was determined for ^{197}Au so as to obtain a good agreement between calculated and experimental nucleon cross sections over the energy range extending from 10 keV to 30 MeV. The transmission coefficients which can be obtained from these neutron and proton potentials are used in statistical model calculations of (n,2n) and (n,p) cross sections, taking into account preequilibrium emission.

2. Optical model potential

The ^{197}Au target nucleus is here assumed, as a first approximation, to be spherical though it lies between the transitional Pt isotopes and the double closed shells Pb region. This choice is discussed later.

The potential parameters are determined at first for the neutron interaction. They are determined so as to reproduce the s- and p-wave strength functions S_0 [1] and S_1 [2], the potential scattering radius at low energy R' [2], and the energy variation of the total cross section σ_T over the full energy range [3]. The analysis of σ_T is restricted in a first stage to the energy range 10 keV-8 MeV where the volume absorption effects are generally believed to be small. In the second stage the complex isospin term in the nucleon optical potential is determined in an adjustment of the potential depths, so as to obtain satisfactory shapes for the proton angular distributions at 17 MeV [4], 22.2 MeV [5] and 28 MeV [6]. The competition between surface and volume absorptions is also determined at this step of the study and energy variation laws are obtained for both of them.

3. Analysis of neutron and proton data

The nucleon spherical optical potential U is written as usual :

$$U = -V f(r, a_V, R_V) + 4i\, W_D a_D \frac{d}{dr} f(r, a_D, R_D) - W_V f(r, a_V, R_V) + 2\, \lambda_\pi^2 V_{so} \frac{1}{r}\frac{d}{dr} f(r, a_{so}, R_{so})\, \vec{l}.\vec{s} + V_c$$

where $f(r,a_i,R_i)$ is a Woods-Saxon form factor, $R_i = r_i A^{1/3}$ and V_c is the Coulomb potential. This term is included in U only for the proton potential. The potential parameters are gathered in Table 1. The Coulomb correction term is calculated according to the prescription given by Satchler [7]. The potential given by Perey [8] is adopted for the spin-orbit term.

3.1. Neutron data

In Table 2, a comparison is shown between experimental and calculated values (at 10 keV) of S_0, S_1 and R'. The agreement is good except for the potential scattering radius for which the calculated value is high. This trend may explain the large disagreement between the experimental and calculated values for the total cross section (Fig. 1) at 10 keV. In spite of this observed disagreement extending up to about 300 keV, the energy variation of σ_T [2,3] is well reproduced in the full energy range. The origin of this behaviour below 300 keV is not clear, but it might be related to the original assumption made for the shape of ^{197}Au (i.e. spherical nucleus).

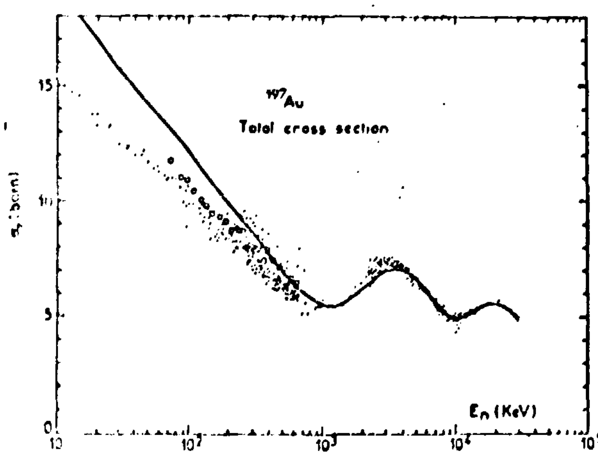

Fig. 1 - Comparison between calculated and measured σ_T (O Ref. 2), • Ref. 3)).

As an illustration of predictions which can be made for neutron angular distributions without any particular adjustment, a comparison is shown at 8.05 MeV (Fig.2) between the measurements by Holmqvist et al. [9] and our calculations. These measurements seem to include, in addition to the elastic scattering angular distribution, some inelastic scattering contributions associated to a few hundred keV neutron energy resolution involved in these experiments. Thus, inelastic scattering cross sections to the first excited states have been roughly estimated by assuming that the sum of them may be represented by the inelastic scattering cross section $\sigma_{2^+}(\theta)$ to the first 2^+ excited state of the even-even vibrational core ^{196}Pt. In Fig. 2 are shown the calculated elastic scattering angular distribution $\sigma_{el}(\theta)$ and the sum $[\sigma_{el}(\theta)+\sigma_{2^+}(\theta)]$. A qualitative good agreement is obtained with the measurements.

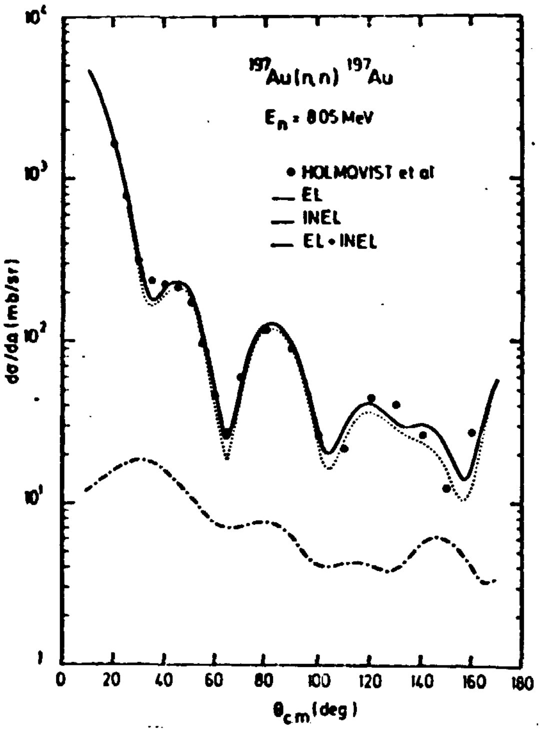

Fig. 2 - Comparison between calculated and measured $\sigma_{el}(\theta)$(Ref.9)) at E_n = 8.05 MeV.

3.2. Proton data

The comparison between proton potential predictions and proton elastic scattering angular distributions at 17 MeV [4], 22.2 MeV [5] and 28 MeV [6] is generally good. As an example, such a comparison is shown in Fig. 3 at 28 MeV where the data are known to be corrected for inelastic scattering components.

3.3. (n,2n) and (n,p) cross sections

The (n,2n) and (n,p) cross sections calculated by a statistical model can constitute a good, though indirect, test for the parametrisation of this nucleon optical model. From threshold to 12 MeV, a spin-parity dependent model was used to calculate (n,2n) cross sections. Above this energy a spin-parity independent formalism including preequilibrium emission was employed [10]. The (n,p) cross sections were calculated using only this last model. As can be seen in Fig. 4, a very good agreement with the recent evaluation [11] is obtained, partly due to the convenient optical model parametrisation. The correction due to the preequilibrium emission, though improving slightly this agreement, is not very important for the (n,2n) cross section, but it is essential for the (n,p) cross section. For these two reactions, the two-body matrix element used in the preequilibrium calculation was of the form $|M|^2 = 250/(A^3E)$ where A is the mass number and E the excitation energy of the emitting nucleus.

4. Discussion

By determining an adopted and unique parameters set for the optical potential, we have shown that it is possible to give a good interpretation of many neutron as well as proton data for ^{197}Au. It remains however to improve the fit to the total cross section at low energy. From a recent and preliminary work, it appears that most of the difficulty can be removed by considering this nucleus as deformed. Such a study is in progress.

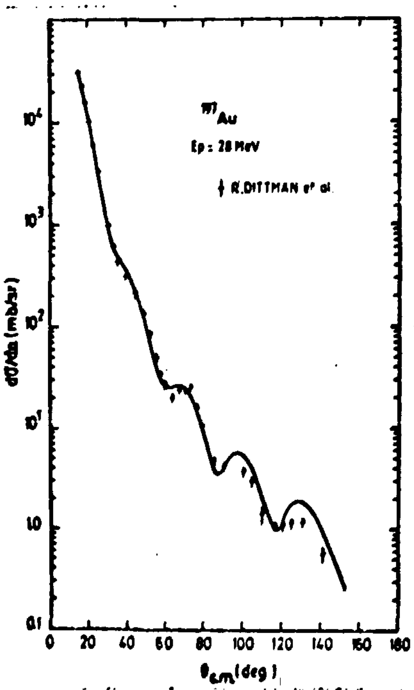

Fig. 3 - Comparison between calculated and measured $\sigma_{el}(\theta)$ (Ref.6)) at E_p = 28 MeV.

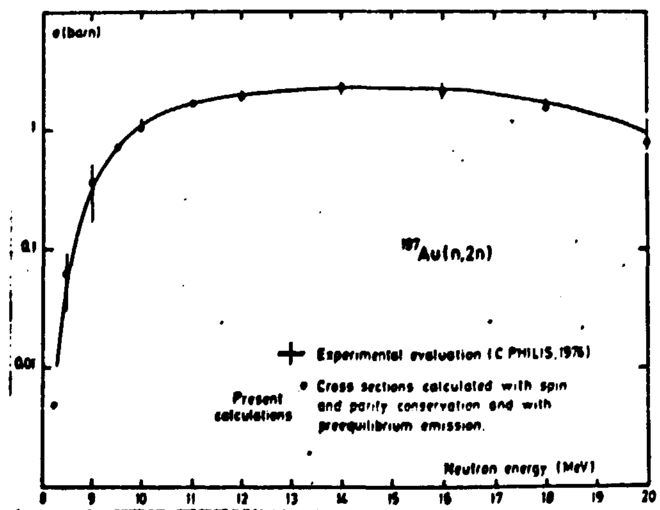

Fig. 4 - Comparison between calculated and evaluated σ (n,2n) (Ref. 11)).

References

1) J. Morgenstern, CEA Report, CEA-R-3609 (1968).
2) H.S. Camarda, Phys. Rev. C9 (1974) 28.
3) D.I. Garber and R.R. Kinsey, BNL-325, 3d ed., Vol. II (1976).
4) I.E. Dayton and G. Schrank, Phys. Rev. 101 (1956) 1358.
5) C.B. Fulmer, Phys. Rev. 125 (1962) 631.
6) R. Dittman, H.S. Sandhu, R.K. Cole, Ch. N. Waddell, Nucl. Phys. A126 (1969) 592.
7) G.R. Satchler, in "Isospin in Nuclear Physics" ed. by D.H. Wilkinson, North-Holland Publ. Comp., Amsterdam (1969).
8) F.G. Perey, in Proceedings of the 2nd Intern. Symp. on Polarisation Phenomena of Nucleons, Karlsruhe (1965) p. 191.
9) B. Holmqvist and T. Wiedling, Aktiebolaget Atomenergi Report, AE-430 (1971).
10) J. Jary, Report INDC (FR) 10L - NEANDC (E) 175 "L" (1977).
11) C. Philis, O. Bersillon, CEA-Report, CEA-R-4826 (1977).

TABLE 1

$V = 52.06 \pm 20\left(\frac{N-Z}{A}\right) + \Delta_c - 0.32E$ $\quad r_V = 1.24 \quad a_V = 0.67$

$$W_D = \begin{cases} 6.58 \pm 10\left(\frac{N-Z}{A}\right) + 1.30\sqrt{E}, & E \leq 10 \text{ MeV} \\ 10.69 \pm 10\left(\frac{N-Z}{A}\right) - 0.15\,(E-10), & E \geq 10 \text{ MeV} \end{cases} \quad r_D = 1.24 \quad a_D = 0.47$$

$$W_V = \begin{cases} 0, & E < 10 \text{ MeV} \\ 0.25E - 2.50, & E > 10 \text{ MeV} \end{cases} \quad V_{SO} = 6.20 \quad r_{SO} = 1.12 \quad a_{SO} = 0.47$$

Coulomb radius : $r_c = 1.19$; $\Delta_c = 6.316$ (for protons)

^{197}Au . Nucleon spherical optical potential parameters (energies in MeV, lengths in fermi).

TABLE 2

$S_0 \times 10^4$		$S_1 \times 10^4$		R' (fm)	
exp.	$1.80^{+0.40}_{-0.30}$ (a)	exp.	$0.40^{+0.40}_{-0.30}$ (b)	exp.	9.30±0.35 (b)
calc.	1.60	calc	0.53	calc	10.01

(a) : Ref. 1) ; (b) : Ref. 2) .

Comparison between experimental and calculated values (E_n = 10 keV) for the s- and p-wave strength functions and potential scattering radius.