4.7 Physical Interpretation of Anomalous Absorption of Partial Waves by Nuclear Optical Potentials

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Dedicated to late Prof. S.B.P. Wickramasuriya

ABSTRACT

A formula for semi-classical elastic S-matrix element has been derived by Brink and Takigawa for a potential having three turning points with a potential barrier (see [1]). If S_{lj} denotes the S-matrix element corresponding to angular momentum l and total angular momentum j, S_{lj} is given, in the usual notation, by

$$S_{lj} = \exp(2i\delta_1)\left\{\frac{1+\overline{N}(i\varepsilon)\exp(2iS_{32})}{N(i\varepsilon)\exp(2iS_{32})}\right\}, \quad (1)$$

where $N(z)$ is defined by $N(z) = \frac{\sqrt{2\pi}}{\Gamma\left(\frac{1}{2}+z\right)}\exp\left(z\ln\left(\frac{z}{e}\right)\right)$ and $\varepsilon = \frac{-i}{\pi}S_{21}$.

If $k = \sqrt{\frac{2\mu E}{\hbar^2}}$ is the wave number corresponding to a zero of semi-classical S-matrix element, it can be shown that

$$1 + \frac{1+\exp(2\pi\varepsilon)}{N(i\varepsilon)}\exp(2iS_{31}) = 0$$

and one obtains

$$S_{31} = (2n+1)\frac{\pi}{2} + \frac{1}{2i}\ln\left(\frac{N(i\varepsilon)}{1+\exp(2\pi\varepsilon)}\right) \quad (2)$$

which is a necessary and sufficient condition for the semi-classical S-matrix element to be zero.

Now, $S_{lj} = 0$ means the absence of an outgoing wave. Since the asymptotic wave boundary condition for the corresponding partial wave $U_{lj}(k,r)$ is given by

$$U_{lj}(k,r) \sim U_l^{(-)}(k,r) - S_{lj}U_l^{(-)}(k,r), \quad (3)$$

where $U_l^{(-)}$ and $U_l^{(+)}$ stand for the incoming and outgoing Coulomb wave functions respectively.

A new phenomenon was discovered by M. Kawai and Y. Iresi (See[2]) in case of elastic scattering of nucleons on composite nuclei. They found that elastic S-matrix element becomes very small for special combinations of energy (E), orbital angular momentum (l), total angular momentum (j) and target nucleus. It has been found that this phenomenon is universal for light ion elastic scattering (see[3]).

To the zero S-matrix element corresponding to this phenomenon, we

have found that $\frac{1}{2i}\ln\frac{N(i\varepsilon)}{1+\exp(2\pi\varepsilon)}\sim 0$ both in case of deuterons scattering on nuclei and ^{4}He scattering on ^{40}Ni ,which means $S_{lj}=(2n+1)\frac{\pi}{2}$. It can be shown [1] that the S-matrix element can be put into the form $S_{lj}\approx\frac{e^{2iS_1}}{N}+\frac{e^{2iS_3}}{N^2}=\eta_B+\eta_I$ assuming that $\left|e^{2iS_{32}}\right|\leq\left|N\right|^2$, where η_B and η_I stand for the amplitude of the reflected wave at the external turning point and the amplitude of the reflected wave at the innermost turning point, respectively. Then it is clear that $S_{lj}=0$ is due to the fact that the destructive interference of these waves in the asymptotic region.

References:

1. D. M. Brink and N. Takigawa, Nucl. Phys. A 279, 159 (1976)
2. M. Kawai and Y. Iresi, Phys. Rev. C 31, 400 (1985)
3. R. A. D. Piyadasa, M.Sc. Thesis, Kyushu University(1986)