nuclear field, one finds that the nonrenormalizable divergences do not cancel, but, on the contrary, are additive. For each vector meson line (included in the vertex) one must write

$$f_1^2(\gamma_\nu \cdots \gamma_\mu)\ (\delta_{\nu\mu} - k_\nu k_\mu \mu_1^{-2})/(k^2 - \mu_1^2), \qquad (1)$$

where the dots denote an arbitrary part of the diagram, and for each scalar meson line, one must write

$$-(f_2^2/\mu_2^2)\ (\mathbf{k} \ldots \mathbf{k})\ (k^2 - \mu_2^2)^{-1}. \qquad (2)$$

The minus sign in the last expression is due to the fact that one of the factors **k** describes the creation of a meson, while the other describes annihilation (this sign also follows from Feynman's rule[1]: k is the difference between the initial and final momentum of the nucleon).

It follows from (1) and (2) that the divergences connected with the factor **k** in the numerator, will only cancel if $f_1^2/\mu_1^2 = -f_2^2/\mu_2^2$, i.e., if one of the charges is imaginary.

[1] R. P. Feynman, Phys. Rev. **76**, 769 (1949).

[2] D. B. Beard and H. A. Bethe, Phys. Rev. **83**, 1106 (1951).

[3] Schweber, Bethe and de Hoffman, *Mesons and Fields*, Row, Peterson and Co., Evanston, Ill., 1955, Vol. 1.

[4] G. Wentzel, *Quantum Theory of Fields*, Interscience Publishers, Inc., New York, 1949.

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Relative Cross Sections for $n-p$ Reactions Involving Nuclei with Several Stable Isotopes

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WHILE examining the literature on nuclear reactions the author noticed a regular variance in the $n-p$ and $n-\alpha$ reaction cross sections (for 14 mev neutrons) in the stable isotope series of individual elements. It follows from the data of Clarke and others[1] that the $n-p$ and $n-\alpha$ reaction cross sections for the various isotopes of an element decrease with increasing isotopic mass number as a rule (in seven of the nine investigated cases); moreover, in six of the seven cases, they decrease almost exactly by a factor of two or four*. In order to verify this regularity and define it more precisely, a program was initiated for the experimental determination of $n-p$ reaction cross sections of nuclei with several stable isotopes (Zr, Cd, Ti, Sr and Ca).

Specimens of salts of the elements under investigation were bombarded with 14 mev neutrons and dissolved; radioactive isotopes of Y, Ag, Sc, Rb and K produced by the $n-p$ reactions were then separated from the solution and their activity was measured with a standard cylindrical geiger counter. An analysis of the decay curves then yielded the activity of each isotope from the time the bombardment ended. Absolute activities were computed by correcting for decay during bombardment time and for absorption of radiation by the walls of the counter. The latter correction was determined in each case by means of special absorption measurements. This correction is not very large inasmuch as the reaction products of all investigated reactions [except for the reaction Ti(n, p)Sc] emit hard β-rays; therefore, even a large error in the determination of this correction cannot seriously affect the final result.

In this fashion relative cross sections were obtained for four isotopes of Zr, four of Cd, two of Sr, two of Ca; only rough preliminary results were obtained for Ti:

$$\sigma\,\mathrm{Zr}^{90} : \sigma\,\mathrm{Zr}^{91} : \sigma\,\mathrm{Zr}^{92} : \mathrm{Zr}^{94} = 1 : 0.74 : 0.46 : 0.20;$$

$$\sigma\,\mathrm{Cd}^{106} : \sigma\,\mathrm{Cd}^{111} : \sigma\,\mathrm{Cd}^{112} : \sigma\,\mathrm{Cd}^{113} = 5.00 : 1 : 0.71 : 0.52;$$

$$\sigma\,\mathrm{Sr}^{86} : \sigma\,\mathrm{Sr}^{88} = 1 : 0.46;$$

$$\sigma\,\mathrm{Ca}^{42} : \sigma\,\mathrm{Ca}^{44} = 1 : 0.24;$$

$$\sigma\,\mathrm{Ti}^{47} : \sigma\,\mathrm{Ti}^{48} : \sigma\,\mathrm{Ti}^{49} = (1) : (0.25) : (0.06)$$

Similar relations are presented below for five pairs of other isotopes computed from Clarke's data.

$$\sigma\,\mathrm{Mg}^{24} : \sigma\,\mathrm{Mg}^{25} = 1 : 0.23;\ \ \sigma\,\mathrm{Si}^{28} : \sigma\,\mathrm{Si}^{29} = 1 : 0.46;$$

$$\sigma\,\mathrm{S}^{32} : \sigma\,\mathrm{S}^{34} = 1 : 0.23;\ \ \sigma\,\mathrm{Zn}^{64} : \sigma\,\mathrm{Zn}^{66} = 1 : 0.26;$$

$$\sigma\,\mathrm{Ge}^{70} : \sigma\,\mathrm{Ge}^{72} = 1 : 0.50.$$

The following deductions can be made from the adduced data:

1) the $n-p$ reaction cross section for nuclei with several isotopes decreases considerably as

a rule, with increasing isotopic mass. This decrease is more noticeable for light nuclei and less so for heavy ones;

2) for the case of light nuclei, increasing the mass number by two, results in a 4-fold (Ca, Si, S, Zn) or a 16-fold [Mg, (Ti)] decrease in the reaction cross section, while a 2-fold decrease occurs for the heavy elements (Sr, Zr, Cd, Ge);

3) the results which have been obtained apparently disagree with the statistical theory of nuclear reactions, and perhaps provide evidence for the preservation of a shell structure even at high excitation energies.

Some of the data cited above were obtained by O. I. Ivanov and E. E. Vinogradov', students at Moscow State University, in fulfillment of their theses.

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* There is evidence to suggest that Clarke's data, which represents an exception to this rule ($Zr^{90,94}$, $Pd^{104,105}$, $Ge^{72,73}$), is uncertain because the experimental method is less reliable in these cases.

[1] E. B. Pauli and R. L. Clarke, Canad. J. Phys. 31, 267 (1953).

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