CABIBBO-RADICATI SUM RULE AND PHOTODISINTEGRATION OF THREE-NUCLEON NUCLEI

S. B. Gerasimov
Joint Institute for Nuclear Research
Submitted 18 March 1967
ZhETF Pis'ma 5, No. 11, 412-414 (1 June 1967)

The Cabibbo-Radicati sum rule [1-3] is applicable to any system with nonzero isospin and relates the isovector radius of charge distribution with the cross sections of the transitions brought about by the isovector part of the electromagnetic-current operator. In this note we consider the application of the Cabibbo-Radicati sum rule to the isotopic doublet of nuclei He^3 and H^3.

The sum rule is of the form

$$\frac{1}{3}\left(2 \langle r^2 \rangle^{He^3} - \langle r^2 \rangle^{H^3}\right) = \left(\frac{\mu^{He^3} - \mu^{H^3}}{2M}\right)^2 + \frac{1}{2\pi^2 \alpha} \int_{\omega_{thr}}^{\infty} \frac{d\omega}{\omega} \left(2\sigma^v_{1/2}(\omega) - \sigma^v_{3/2}(\omega)\right), \qquad (1)$$

where $\langle r^2 \rangle$ is the rms charge-distribution radius, μ the magnetic moment in nuclear magnetons, $\sigma^v_{1/2}$ and $\sigma^v_{1/2}$ the total cross sections of the transitions to final states with isospins 1/2 and 3/2 with allowance for the action of the isovector part of the current operator only, $\alpha = 1/137$ and M is the nucleon mass.

An important fact is that the contribution made to the integral (1) by meson photoproduction processes is negligible. It can be estimated by using the approximate additivity of the cross sections for meson photoproduction on the nucleons of the nuclei, and the numerical calculations of the Cabibbo-Radicati sum rules for the nucleon [4]. In nuclear photodisintegration processes, the probability of "isoscalar" transitions (i.e., transitions induced by the isoscalar part of the current operator) is small compared with the "isovector" ones. Indeed, in the long-wave approximation the operator of electric dipole absorption has no isoscalar part at all, and the integral contribution of all the higher multipoles is small compared with the E1 absorption. With accuracy not worse than 10%, we can replace in formula (1) the "isovector" disintegration cross sections by the experimental cross sections for the photodisintegration of He^3 [5]. The photodisintegration of He^3 has two channels:

$$\gamma + He^3 \to p + d, \qquad (2)$$

$$\gamma + He^3 \to n + p + p. \qquad (3)$$

The final state of the two-particle channel (2) has an isospin I = 1/2, and values I = 1/2 and 3/2 are possible in the three-particle channel (3). Substituting in (1) the experimental values of the magnetic moments and radii [6] of the three-body nuclei: $\mu^{He^3} = -2.12$, $\mu^{H^3} = 2.98$, $\langle r^2 \rangle^{He^3} = 3.5\ F^2$, $\langle r^2 \rangle^{H^3} = 2.9\ F^2$, and assuming that the contribution of photoproduction to the right side of (1) is equal to 0.3 mb [4], we obtain the following interesting result: in order for the Cabibbo-Radicati sum rule (1) to be valid, the reaction of the three-particle decay of the nucleus (3) must go essentially via a state with I = 3/2.

If we put

$$2\sigma_{-1}(I = 1/2) - \sigma_{-1}(I = 3/2) = 2\sigma_{-1}(\gamma, p) + [2w(1/2) - w(3/2)]\sigma_{-1}(\gamma, n), \tag{4}$$

where σ_{-1} are integrals similar to (1) of the corresponding cross sections and w(I) is the averaged probability of encountering the value of the isospin I in channel (3), then, assuming w(1/2)/w(3/2) = 0, 0.1, 0.3, and 0.5, we get in the right side of (1) the values 11.6, 14.2, 18.3, and 21.4 mb. The value of the left side is in this case 13.7 mb. Thus, assumptions of quite general character lead to a result of practical significance, namely that the connection between channels (2) and (3) via the unitarity condition is immaterial. A study of the mechanism of intensification of the transitions in the state with I = 3/2 in the three-pacticle reaction channel (3), predicted on the basis of the sum rule, may be of interest in connection with the problem of the "trineutron" n^3, which has been widely discussed in the recent literature (see [7]), and the problem of excited levels in three-body nuclei.

In conclusion, I am grateful to A. M. Baldin and V. N. Fetisov for interest in this work.

[1] N. Cabibbo and L. Radicati, Phys. Lett. 19, 697 (1966).
[2] V.N. Gribov, B. L. Ioffe, and V. M. Schekhter, Phys. Lett. 21, 457 (1966).
[3] R. N. Faustov, R. E. Kallosh, and V. G. Pisarenko, JINR Preprint E-2865, Dubna, 1966.
[4] F. J. Gilman and H. J. Schnitzer, Phys. Rev. 150, 1362 (1966).
[5] A. T. Varfolomeev and A. N. Gorbunov, JETP 47, 30 (1964), Soviet Phys. JETP 20, 20 (1965).
[6] H. Collard, R. Hofstadter, E. B. Hughes, A. Johansson, M. Yearian, R. B. Day, and R. T. Wagner, Phys. Rev. 138, B57 (1965).
[7] K. Okamoto and B. Davies, Phys. Lett. 24B, 18 (1967).

NONLINEAR QUANTUM PSEUDORESONANCE IN METALS

M. Ya. Azbel' and L. B. Dubovskii
Institute of Theoretical Physics, USSR Academy of Sciences
Submitted 21 March 1967
ZhETF Pis'ma 5, No. 11, 414-417 (1 June 1967)

Nonlinear effects in metals placed in an electromagnetic field are usually small. In a quantizing constant magnetic field H, however, as is well known (see [1]), the magnetic moment M and the conductivity σ oscillate with a frequency $cS/e\hbar H \gg 1$. As noted in [2], a nonlinearity appears in these oscillating terms even in a relatively weak alternating field. To this end it is sufficient to have an external-field amplitude H_1 on the order of the period of the quantum oscillations, i.e., $H_1 \gtrsim H(e\hbar H/cS)$(S - area of the Fermi-surface section).

To observe quantum oscillations it is necessary to have a sufficiently strong magnetic field ($h\Omega > 2\pi^2 kT$, $\Omega\tau > 1$, the latter is equivalent to $r < \ell$. Here $\Omega = eH/m^*c$, τ and ℓ are the time and mean free path of the electrons, and r their Larmor radius).

Nonlinearity takes place at all frequencies. The effect reaches a maximum at $\omega \ll 1$ (ω is the frequency of the alternating field), when the system is able to "attune itself" to the alternating field existing at the given instant, and can "follow" the frequency.

For simplicity of calculation we assume that the normal skin effect conditions are satisfied: $\delta \gg \ell$, and therefore also $\delta \gg r$ (δ - thickness of skin layer). At distances r and ℓ we can therefore assume the field to be homogeneous and all the relations to be local. It is therefore possible to use in the main approximation the formulas obtained for the static case.