factors can be a symmetric function (antisymmetrization of a function which is symmetric with respect to even two particles gives a vanishing result). Thus no factor can be $\Psi^{J'}_{M}(1, 2)$, where J' is odd (j is a half integer).

The operator of a $M1$ transition is a pseudovector operator; therefore, the matrix element vanishes for a transition between a state with the wave function $\Psi^0_0(1,2)$ and a state with the wave function $\Psi^{J'}_{M'}(1, 2)$, where J', as we have seen, can only be even. This simply denotes that transitions with $\Delta v \neq 0$ are forbidden.

It is expedient in practice to investigate experimentally the satisfaction of the selection rules for v only for nuclei which are heavier than Ca^{40}_{20}, since nuclei between O^{16}_8 and Ca^{40}_{20} evidently do not possess a shell structure, $1d$ and $2s$ configurations are highly mixed.

In particular, for nuclei with a $1f_{7/2}$ shell these experiments can determine whether jj or intermediate coupling takes place[5] and whether collective interactions are significant. v will be a good quantum number only when $j-$ is a good quantum number and collective effects are unimportant. Experimental investigations of the accuracy of v are naturally performed through experimental investigations of the accuracy of j [6].

1 G. Racah, Phys. Rev. **63**, 367 (1943).

2 A. Edmonds and B. Flowers, Proc. Roy. Soc. (London) **214A** 515 (1952).

3 C. Schwartz and A. de-Shalit, Phys. Rev. **94**, 1257 (1954).

4 M. Umesawa, Progr. Theor. Phys. **8**, 509 (1952).

5 D. R. Inglis, Rev. Mod. Phys. **25**, 390 (1953).

6 J. B. French and B. J. Raz, Phys. Rev. **98**, 1523 (1955).

Translated by I. Emin
186

Gamma Quanta Emitted by I, Rh and Co Nuclei in Thermal Neutron Capture

I. V. ESTULIN, L. F. KALINKIN AND A. S. MELIORANSKII

Moscow State University

(Submitted to JETP editor April 22, 1956)

J. Exptl. Theoret. Phys. (U.S.S.R.) **31**, 886-887 (November, 1956)

THE most reliable data on the energy and the absolute yield of γ-quanta emitted by nuclei upon thermal neutron capture have been obtained by Kinsey's group[1] and by the Soviet scientists Groshev, Ad'iasevich and Demidov[2,3]. In Kinsey's work[1], only γ-rays with energies greater than 3 mev were detected while in the work of Ref. 2, the spectrum of γ-quanta with energies greater than 0.3 mev was investigated. Meanwhile, measurements carried out with the help of scintillation spectrometers[4,5] proved the presence of discrete lines in the low energy part of the spectra. The authors working with scintillation spectrometers were not able to determine the absolute intensities of the observed lines.

In the present work, the energies and absolute intensities of γ-quanta with energies of 50 to 600 kev emitted by I, Rh and Co nuclei during thermal neutron capture were determined. In the work, a scintillation spectrometer was used with a NaI (Tl) crystal of cylindrical shape (height 9 mm, diameter, 28 mm). The resolving power of the spectrometer, η, depends on the energy of the γ-quanta (E_γ) according to the law

$$\eta = 186\, E_\gamma^{-1/2} + 2.5, \qquad (1)$$

where E_γ is expressed in kev and η in percent. In experiments carried out with radioactive emitters having monoenergetic γ-ray spectra, the efficiency of the spectrometer ϵ_Φ, was determined, enabling one to convert the area of the photo peak to the number of γ-quanta falling on the NaI (Tl) crystal.

A heavy water physics research reactor[6] was used in this work as a source of thermal neutrons. A well-collimated beam of neutrons came out of a horizontal channel in the reactor shielding. A target of the material being investigated was located in the center of the beam. A NaI(Tl) crystal and a photomultiplier tube were placed under the target, and were carefully shielded with lead and with boron carbide . A channel of 10 or 15 mm diameter, used as a collimator for γ-rays coming from the target to the NaI(Tl) crystal, was located in the spectrometer shielding. The aperture of the γ-ray collimator was covered with boron carbide of 0.3 gm/cm^2 thickness, blocking the passage of thermal neutrons scattered in the target.

In the measurement of γ-rays from the capture of neutrons, measurements were made with an open beam of thermal neutrons, N_0, and with a beam of neutrons filtered at the exit of the neutron collimator by a B_4C shield (N_1). The effect of thermal neutrons in the target N is equal to the difference between these two values:

$$N = N_0 - N_1.$$

The photopeaks of soft γ-rays in the spectra of the targets investigated that are emitted by nuclei as a result of thermal neutron capture are seen on a background of impulses from harder γ-quanta. The presence of this "base" limits the accuracy of the determination of the areas of the photopeaks. In order to lower the background due to hard γ-quanta, the study of the low energy part of the γ-ray spectra included measurements of the absorption of the γ-quanta in lead. In such a way, the γ-ray spectra absorbed in thin lead filters were measured. In these spectra, it is possible to isolate the desired photopeak area with certainty; this area is directly related to the intensities of the measured γ-rays.

In order to determine the number of γ-quanta of a given energy resulting from the capture of one neutron, it is necessary to know the neutron current falling on the target as well as the solid angle subtended by the target relative to the NaI(Tl) crystal. With the goal of measuring these quantities experimentally, we replaced in the neutron beam the target being investigated with a B_4C target, similar in shape to the target of the material being investigated. The B_4C target completely absorbed the thermal neutrons falling on it. Comparison of the area of the photopeak from 482 kev γ-quanta, emitted by a B_4C target, with the area of the photopeak arising from the target of the material being investigated permitted determination of the emission of γ-quanta during capture of a single neutron. Here use was made of the absorption cross section for thermal neutrons[7] and the experimentally determined efficiency of the scintillation spectrometer. The results of measurements on I, Rh and Co are presented below.

During the measurement of thermal neutron capture, γ-rays from I nuclei, γ-quanta with energy $E = 135 \pm 4$ kev, not apparent earlier in the work of other authors[4,5], were observed. The results of one of the experiments with an I target are presented in the Figure. The photopeak of γ-rays with 135 kev energy is clearly seen. The intensity of these γ-quanta per 100 captures of thermal neutrons was $n = 30$. The accuracy in the determination of the absolute yield is 15%. On the Figure, to the left of the principal photopeak, there are seen two small instrumental peaks. In addition, a photopeak from γ-quanta of energy 510 kev is noticed in the spectrum of the γ-radiation from an I target. It is possible, however, that these quanta have a secondary origin. Gamma-quanta with an energy of 255 kev, observed in Ref. 5 on the reaction I(n,γ), did not appear in our measurements.

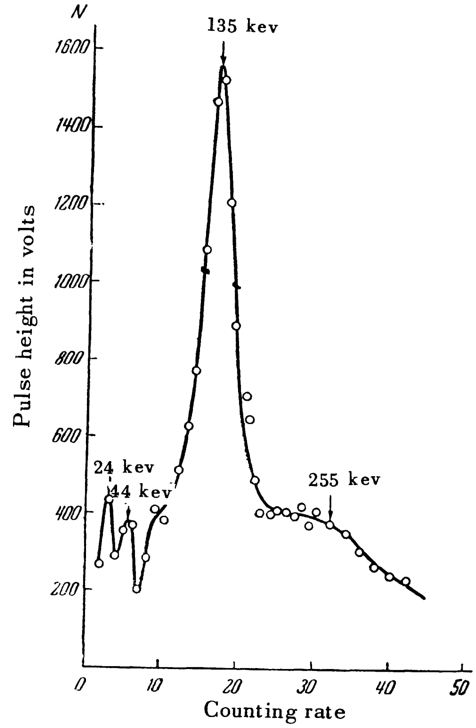

FIG. The γ-ray spectrum from Iodine.

Four discrete lines, with energies $E_1 = 217 \pm 4$; $E_2 = 176 \pm 4$; $E_3 = 133 \pm 4$; $E_4 = 96 \pm 4$ kev, and with intensities (for 100 captures of thermal neutrons) respectively equal to $n_1 = 9.3$, $n_2 = 18$, $n_3 = 8$ and $n_4 = 16$, have been observed as the result of the measurement of the γ-ray spectra emitted by Rh nuclei upon thermal neutron capture. The ratio n_1/n_4 is determined with an accuracy of 15-20%. The lines found cannot be connected with the activation of the target, since they differ in energies from the γ-quanta from the isomer Rh^{104} [8]. In the work of Hamermesh and Hummel[4], γ-quanta of energies 80 and 160 kev found in the γ-radiation from radiative capture of neutrons by Rh nuclei, were assigned in error to target activation. In this work, it is probable that the most intense of the γ-rays registered by us were detected. In the work of Kinsey and Bartholomew[9], the energies and intensities of the hardest γ-quanta emitted upon slow neutron capture were measured. On the basis of these data, it is possible to establish the energies of the low-lying levels of the Rh^{104} nucleus. The γ-lines found by us correspond to transitions between these levels.

Gamma-quanta with energies $E_1 = 276$ and $E_2 = 226$ kev and approximately equal intensities of about 20 γ-quanta per 100 neutron capture have been observed in the measurement of the spectra of the γ-rays from the radiative capture of thermal neutrons by Co nuclei. The energies of the γ-quanta E_1 and E_2 are in agreement with the data from the work of Reier and Shamos[5].

In conclusion, the authors thank A. M. Safronov and the association of co-workers operating the physics reactor for their help in the work.

[1] B. B. Kinsey and G. A. Bartholomew, Canad. J. Phys. **31**, 537 (1953).

[2] Groshev, Ad'iasevich and Demidov, Papers at the International Conference on the peaceful applications of atomic energy, Geneva, 1955; Physics Research, p. 252, Acad. of Sci., USSR, Moscow, 1955.

[3] Ad'iasevich, Groshev and Demidov, Session of the Acad. of Sci., USSR, on the peaceful applications of atomic energy, July 1-5, 1955; Meeting of the division of physical-mathematicl sciences, publication of the Acad. Sci., USSR, Moscow, 1955.

[4] B. Hamermesh and V. Hummel, Phys. Rev. **88**, 916 (1952).

[5] M. Reier and M. H. Shamos, Phys. Rev. **95**, 636 (1954).

[6] Alikhanov, Vladimirskii, Nikitin, Galanin, Gavrilov and Burgov, Papers at the International Conference on the peaceful applications of atomic energy, Geneva, 1955; Reactor construction and the theory of reactors, p. 105, Acad. of Sci., USSR, Moscow, 1955.

[7] D. J. Hughes, *Pile Neutron Research*, IIL, Moscow, 1954.(originally published in the United States by Addison-Wesley).

[8] Jordan, Cork and Burson, Phys. Rev. **90**, 463 (1953).

[9] B. B. Kinsey and G. A. Bartholomew, Canad. J. Phys. **31**, 1025 (1953).

Translated by F. Ajzenberg-Selove
183

Concerning a Certain Possibility in Quantum Field Theory

IU. M. LOMSADZE
Moscow State University

(Submitted to JETP editor February 28, 1955)
J. Exptl. Theoret. Phys. (U.S.S.R.) **31**, 887-889 (November, 1956)

THE author has attempted to overcome the well-known difficulties of contemporary relativistic quantum field theory which result, first, from the appearance of irremovable infinities in many "unrenormalizable" variants of the theory (among which are evidently all variants with an interaction Hamiltonian which either consists of the product of more than three field operators or contains the derivatives of these operators) and, secondly, from the divergence of series that are obtained after the elimination of all infinities in the "renormalizable" variants (particularly in electrodynamics).

It would seem that the explanation of these difficulties must be sought not in a deficiency of the theory itself but in a short-coming of the method that is used to solve the equations of the theory (the Lomonoga-Schwinger equations), namely, the perturbation method (the decomposition of the desired solution in a MacLaurin series of powers of the field binding constant g). In other words, the series which is obtained formally in the course of the solution, because of the illegitimacy of this very expansion within the framework of ordinary mathematical analysis, does not provide the desired solution in the usual sense of a sum (the limit of the sum of n terms as $n \to \infty$)*.

It can reasonably be asked, however, whether it is possible in some manner to derive from the formally obtained series the solution which was improperly expanded in this very series. In other words, what mathematical operation should be understood by the "sum" of the series so that this "sum" would give the solution formally expanded in the series even when the ordinary concept of a sum leads to an obviously incorrect result ($\equiv \infty$). If the S matrix $S(g, p)$ of a process is selected as the solution of the quantum equations (where p denotes the set of momenta of "real" particles), then, assuming that this S matrix is an analytic function of p, our question can be answered by introducing the following generalizations of the usual concept of the sum of an infinite series, which satisfy general axiomatic requirements (see,