hermetically sealed spectrometer with KCL prism. To absorb moisture and CO_2 found in the air, $CaCl_2$ and KOH were placed inside. The spectrometer was placed closely to a window in the discharge tube made of sodium chloride. The widths of the inlet and outlet slits of the spectrometer were 1mm. As a detector a bolometer was placed directly at the outlet slit of the spectrometer. The sensitive area of the bolometer was 1×8 mm^2 and the sensitivity was 0.57 V/W. The bolometer voltage was amplified using a photo-electrooptical FEOU-15[7] with additional cascade photo-electrooptical amplification. The galvanometer deflection at the output of the FEOU-15 was amplified by a photo-electrooptical amplifier, constructed in our laboratory. The sensitivity of the FEOU-15 was 1.5×10^{-9} V/mm at 2 meters. The application of the additional cascade amplifier increased the sensitivity approximately 90 times.

Emission band was maximum at about 13.7 microns (Fig. 1) was observed in the emission spectrum of CO_2. The band was about 350 times weaker than the band at 4.65μ. Within the limits of accuracy of the measurements the maximum of the observed band coincides with the maximum of one of the two bands in the flame emission spectrum of $CO + O_2$ and of hot CO_2 [5] at 13.85μ.

It should be noted that while the maximum of the emission band at 4.65 μ corresponding to the unsymmetric vibration of the molecule is displaced in the direction of longer wavelength in comparison with the absorption band at 4.25μ, the maximum of the emission band at 13.7μ corresponding to deformed vibration of the molecule is displaced in the direction of the shorter wavelengths as compared with the absorption band at 14.7μ. The band with maximum at 15μ which is observed in the flame spectrum of $CO + O_2$ and hot CO_2 discharge was not observed by us in the excited emission spectrum of CO_2. The absence of the band in the spectrum may be explained by strong absorption of radiation in that region by CO_2 gas that filled the discharge tube. The emitted radiation passes through a distance 1.5 and 8 cm in the discharge tube, depending on the experimental conditions. It is evident that even with a thickness of the absorbing layer as small as 1.5 cm the absorption is so strong that radiation at 15μ is fully absorbed.

The observed dependence of the emission band at 13.7μ on pressure of CO_2 in the discharge tube is shown if Fig. 2. This curve has the same character as the one for the band at 4.65μ [1]. The addition of nitrogen or hydrogen which have no emission spectra in the infrared region, respectively increase and decrease the intensity of the band at 13.7μ(Fig. 3 and 4). In the case of unsymmetric vibration of the molecule CO_2 (the emission band at 4.65μ) the increase of intensity of the emitted radiation also took place on addition of nitrogen. This increase was explained by Terenin and Neuimin by greater efficiency of molecular transfer of the vibrational quanta between molecules of CO_2 and N_2. A similar point of view cannot be taken to explain the increase of the intensity of the band at 13.7 μ on addition of nitrogen, since in that case the vibrational quanta of CO ($\nu \sim 700$ cm^{-1}) and nitrogen ($\nu \sim 2000$cm^{-1}) are very different.

The authors wish to express their gratitude to A. N. Terenin under whose guidance the present work was carried out.

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Translated by M. J. Stevenson
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The Yield and Angular Distribution of Photoneutrons of High Energy

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(Submitted to JETP editor January 24, 1955)
J. Exper. Theoret. Phys. USSR **28**, 746-748 (June, 1955)

A NUMBER of investigations has been carried out in recent years of photonuclear reactions occurring under the action of γ – quanta with energies of the order of tens and hundreds of mev. However, there still does not exist a satisfactory model describing such reactions at photon energies higher than 50 mev. For the construction of a model, studies are required of the emission by the nuclei of protons, as well as of neutrons, under the action of high energy photons. Although there exists a large number of investigations on the

emission of high energy photoprotons, similar investigations for photoneutrons were, until recently, practically non-existent. Moreover, the data on the emission by nuclei of high energy photoneutrons are of great interest, particularly since the most widely held theory of nuclear interaction of high energy protons is based on the so called"double-nucleon" model, according to which the photons interact in the nucleus with the pairs of proton-neutron "quasi-deuterons". Also, it should be noted that there does not yet exist a satisfactory theory describing the function of excitation and the angular distributions at photon energies higher than 50 mev for even the simplest photonuclear reaction, the splitting of deuterium, with which, in accordance with this model, it is necessary to compare the nuclear reactions in complex nuclei.

The absence of data on the yield and the distribution of high energy photoneutrons is associated to a considerable degree with the difficulties of effective registration of these neutrons. In order to obtain such data, we have used a high threshold scintillating detector with an effectiveness of the order of 1-2% based on the reaction $C^{12}(n, 2n)C^{11}$ occurring in the organic luminophors, described in detail in reference 1. With the aid of this detector we have studied the yield and angular distribution of photoneutrons of the nuclei Be, C, Al and Pb produced by retarded radiation having energies up to 250 mev. The diagram of the experiments is shown in Fig. 1. In choosing the dimensions and the form of the sample - sources of neutrons, in addition to fulfilling the requirements for the effective registration of the photoneutron current, we took into account the fact that the thickness of the sample must not exceed 0.4 units, or 0.2 of the path of neutrons with an energy of 30 mev relative to the elastic scattering. Such a thickness of samples (2.7 cm for Be, 4 cm for C, 3 cm for Al and 2mm for Pb) ensured the absence of noticeable distortions in the angular distribution and, moreover, in the yield of photoneutrons of high energy. Crystals of stilbene or tolane with an effective working quantity of carbon up to 10 g were used as detectors of neutrons. The beam of photons was passed through two collimators in lead, total thickness up to 40 cm, lined inside and on the side where the sample neutron sources are located, with an aluminum layer 5 mm thick. In addition, the detectors were screened with a layer of lead 10 cm thick. A special check showed that there was no noticeable activation of the detectors in the experiments without sample-sources of photoneutrons at angles of 45-135° to the direction of the photon beam. Only in the experiments where the yield was studied at angles of 30° and 150° to the direction of the photon beam, the activation due to the background constituted as much as 50% of the activation in the main experiments.

The absolute value of the high energy photon current was determined from the readings of the ionization chamber-integrator. To the readings of this chamber was reduced also the activation of the monitor – fine films of polystyrene, attached to the front wall of the sample – sources of photoneutrons during the irradiation. Comparison of the activities of these films with the activities of graphite detectors of a known effective working mass, made it possible to determine the cross section of the reaction $C^{12}(\gamma, n)C^{11}$ at high energies of photons.

The problem of possible presence in the photon beam of neutrons of high energy, which could be scattered in the direction of the detector, distorting the results of the experiments, was studied in other investigations [2,3]. However it was found that such an impurity, even if it exists, is negligibly small. In order to remove any side activation of the detector (reactions γ, n and p, pn) we have screened it on the side of the source of neutrons with a layer of lead 1.2 cm thick. With this type of protection the activation of the detector is practically independent of the thickness of the screen, that is, it is entirely determined by neutrons.

The form of the excitation function of the reaction $C^{12}(n, 2n)C^{11}$ is given in reference 1. It is found that even with greatly varying assumptions regarding the spectrum of the high energy photoneutrons, for example, for a rectangular spectrum or a spectrum similar to the spectrum of photoprotons of the form $f(E)\,E^{-1.7}$ [4], it is possible, with an error not exceeding 9%, to determine the yield of photoneutrons, taking $\sigma_{n', 2n} \neq 0$ at $E_n \lesssim 30$ mev and $\sigma_{n,2n} = 22 \times 10^{27}$ cm^2 = const at $E_n \gtrsim 30$ mev.

The data obtained for the angular distribution of the photoneutrons emitted by the nuclei Be, Al and Pb at $(h\nu)_{max} = 250$ mev and the nucleus C at $(h\nu)_{max} = 200$ and 250 mev are given in Fig. 2. The differential angular cross section for the angle of 45° for all the nuclei in Fig 2 is taken to be unity. From the point of view of the "double-nucleon model", the angular distribution of the high energy nucleons can be directly determined from the experimental data on the photosplitting of deuterium, taking into account the momentum distribution of "quasi-deuterons" in the nucleus, moreover with very little distortion of the angular distribution of the nucleons. However, the

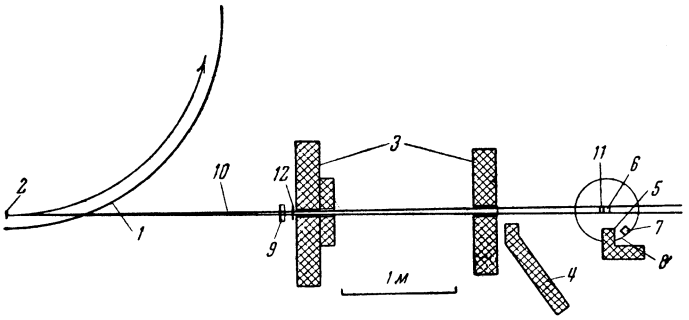

FIG. 1. The diagram of the experiments. *1* – edge of the synchrotron chamber; *2* – the target of the synchrotron; *3* – lead collimators; *4* – auxiliary lead screens; *5* – proton filter; *6* – the sample being bombarded; *7* – neutron detector; *8* – disc supporting the frame; *9* – ionization chamber; *10* – integral chamber-dosimeter; *11* – monitor (graphite or polystyrene).

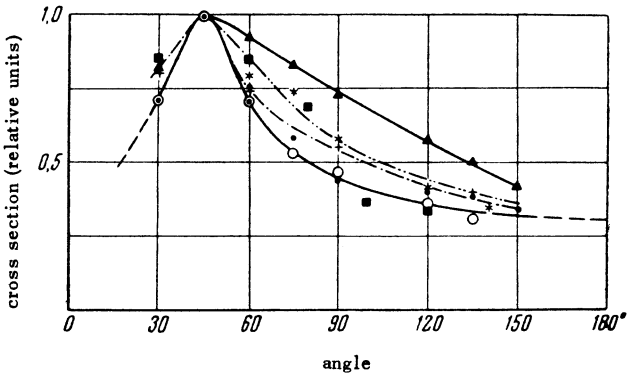

FIG. 2. Angular distribution of photoneutrons with energies higher than 30 mev. ● – C_{250}, + – C_{200}; ▲ – Be_{250}; o – Al_{250}; * – Pb_{250}; ■ – data of work[5].

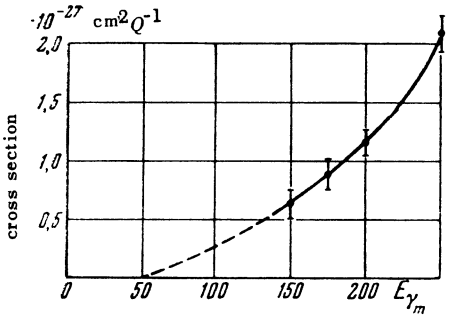

FIG. 3. The dependence of the yield of photoneutrons with energies higher than 30 mev in carbon (in units 10^{-27}cm^2 per eff. quantum) on the maximum energy of retarded radiation.

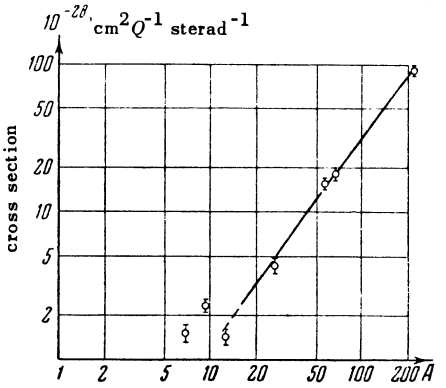

FIG. 4. The dependence of the yield of photoneutrons with energies higher than 30 mev at an angle of 90° (in units 10^{-28}cm^2 per eff. quant steradian on the mass number A).

nucleons produced during the splitting of "quasi-deuterons" may experience new collisions in the same nucleus. Such collisions, in the general case lead to multiple emission of nucleons, registering as photostars in nuclear emulsions. The formation of photostars also results from the processes of the production of mesons with their subsequent absorption in the same nucleus. Thus the angular distribution of the high energy photoneutrons observed in our experiments is, mainly, a result of processes of two types: the pure splitting of "quasi-deuterons" (without the "capture" of nucleons in the nucleus) and the formation of photostars associated mainly with the photoproduction of mesons.

The data given in Fig. 2 for carbon at the maximum photon energies of 200 and 250 mev agree with the results of reference 5, in which the authors measured also for carbon the relative angular distribution of photoneutrons with an energy higher than 50 mev (the yield of such neutrons at an angle of 45° was assumed by them as unity) under the action of retarded radiation with an energy up to 320 mev. We measured the yield of the high energy neutrons from carbon at angle of 45° and at maximum photon energies of 150 and 175 mev. The dependence of the yield on the maximum energy of photons is illustrated in Fig. 3.

Similarly to the angular distribution of the high energy photoneutrons, the excitation function of the yield of such neutrons can be qualitatively interpreted as a result of the superimposition of processes of two types: The formation of photostars and the pure splitting of "quasi-deuterons". The close similarity of the angular distribution of the high energy photoneutrons from the nuclei of carbon, aluminium and lead is analogous to the corresponding results for protons in photostars. For a detailed analysis of the contribution of the various processes in the different nuclei, the study of angular correlation (of the type detected for lithium[6]) between photoprotons and photoneutrons emitted by heavy nuclei becomes significant.

In Fig. 4 the relationship is shown of the yield of photoneutrons with energies higher than 30 mev, at an angle of 90° from the nuclei Li, Be, C, Al, Fe, Cu and Pb at the maximum energy of the retarded radiation of 250 mev. This relationship for the nuclei from C to Pb has approximately the form $\sigma \sim A^{1.4}$; for Li and, particularly, Be the yield of neutrons was found to be higher.

In conclusion it should be noted that our measurements of the cross section of the reaction $C^{12}(\gamma, n)C^{11}$ indicate an increase (in the range of energies of γ – quanta from 50 to 250 mev) in the yield of the direct photoeffect by a value of the order of 10^{-28}cm^2 /eff. quant.

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