indices in two $\eta_{ik}$ coincide; such $\eta_{ik}$ anticommute. As will be shown in the following, however, this situation cannot be ignored, since terms containing combinations of identical operators drop out on integration.

**** An equation of the form (21) was discussed in the literature[2] by analogy with the corresponding formula for a Bose field. In the present case, on account of the anticommutation of the spinors, such an analogy is not valid.

[1] G. Wick, Phys. Rev. 80, 268 (1950)

[2] I. Gel'fand and R. Minlos, Dokl. Akad. Nauk SSSR 97, 209 (1954)

[3] S. Hori, Progr. Theor. Phys. 7, 578 (1952)

[4] J. Anderson, Phys. Rev. 94, 703 (1954)

[5] M. Neuman, Phys. Rev. 83, 1258 (1951)

Translated by E. L. Saletan
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# Gas Bubble Chamber -- A Possible Recorder of the Elementary Act of Interaction of Ionizing Radiation with Matter *

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THE experimentally sucessful[1,2] attempt to record the tracks of ionizing particles in superheated liquid do not exhaust all possibilities of using the bubbles formed along the track to detect the tracks in the liquid. For example, it is possible to record the tracks of ionizing particles by using a supersaturated solution of gas in the liquid: the instantaneous supersaturation produced by the rapid decrease in gas pressure over the surface of the liquid makes the liquid with the gas dissolved in it internally unstable with respect to the formation of centers for the new phase, namely gas bubbles. The passage of the ionizing particle, causing accumulation of ion centers along the track, local heating of the liquid and break-up of the molecules will contribute to the formation of center volumes inside the liquid and convert them into gas bubbles, which produce the track image (a leading role in the initial stage of formation of the volume is played apparently by the initiating repulsion eruption) of closely located molecular complexes of equal charge, gathered by the ions produced by the ionizing particles. The dead time of the work and the diffusion inertia of the growth of the bubble in the "gas" bubble chamber, associated with the local "impoverishment" of the solution can apparently be reduced considerably by selecting the proper operating conditions and using mixture components having a higher mutual solubility (physical or chemical solution of gas in liquid).

The thermodynamic working conditions of the "gas" bubble chamber are more suitable than the thermodynamic working conditions of the "vapor" bubble chamber: "gas" operating conditions do not require that the liquid be heated to increase its vapor pressure, and the use of these conditions will apparently be advantageous for liquid with low surface tension at those temperatures for which the saturated-vapor pressure of the liquid is insufficient to break away center volumes.

The temperature diffusivity of the "gas" working conditions for the bubble chamber and the possibility of independently varying the components of the working mixture, apparently facilitate the transition to large effective working volumes and to the optimum working mixture.

If the idea of "gas" bubble chamber can be put into practice, it will contribute to the creation of a universal, stable and simple instrument for recording the elementary act of interaction of highly-penetrating radiation with matter.

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* Author's own summary of a report prepared in 1953 at the Institute for Physical Chemistry of the Academy of Sciences, USSR.

[1] D. Glaser, Phys. Rev. 91, 762 (1953)

[2] D. Glaser, Nuovo Cim. Suppl. 11, 2 (1954)

Translated by J. G. Adashko
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# On the Problem of the Negative $\pi$-meson Decays

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1. IT is reported[1] that when photographic emulsions were exposed to slow negative $\pi$-mesons, 18 $\pi$-$\mu$ meson decays were observed among 40,000 meson track endings. Convincing arguments are cited to show that it is a question of $\pi$-meson decays and not some concomitant background event.

The observed events[1] are characterized by the presence of an appreciable energy distribution spread of $\mu$ mesons from $\pi\mu$-decays ($\delta E_\rho \approx 0.5$ Mev), which indicates the motion of $\pi$ mesons at the instant of their $\pi\mu$ decays. The kinetic energy of the $\pi$ mesons was estimated to be several tens of Kev[1]. Because of the extremely small stopping time of such $\pi$ mesons, the author[1] concludes that the observed $\pi\mu$-decay events did not take place "in flight", but after formation of mesonic atoms. If this conclusion is correct, then some very interesting deductions follow from it, to which we wish to draw attention in this note.

**2.** The energy distribution of $\mu$ mesons, produced during the $\pi$-meson decays which become part of the mesonic atoms, can be calculated with sufficient accuracy by the method analogous to that used by Podgoretskii and Rosental[2]. This distribution for the $K$-shells of light nuclei which are a part of the emulsion (C,N,O) agrees within the limits of statistical error with the experimental results. One cannot exclude also the decay of the $\pi$ meson while it is on the $L$ and $M$ shells of these nuclei. However, while it is on these shells, the $\pi$ meson must make a transition to the $K$-shell. The duration of the transition to the $K$ shell does not exceed $\sim 10^{-13}$ sec even for the $N$-shell of C,N,O. The probability of the $\pi$-$\mu$ decay during this time is only $5 \times 10^{-6}$. If one assumes that the decay of $\pi$ mesons takes place in the mesonic atoms of the heavy emulsion components (Ag, Br), then the observed energy distribution of $\mu$ mesons corresponds to $\mu$ meson decays on shells with a principal quantum number $n = 10-15$. Simple calculations show that in this case also the duration of transitions to the $K$ shells does not exceed $\sim 10^{-13}$sec. It is necessary to conclude that the observed[1] $\pi$-$\mu$ decay of negative $\pi$ mesons took place in the $K$-shell of the light mesonic atom of (C,N,O) nuclei, which is clear from the known energy distribution of $\mu$-mesons on the $K$-shell of mesonic atoms with light nuclei.

**3.** Such a conclusion strongly contradicts modern conceptions about the properties of $\pi$ mesons. Since about one half of the $\pi$ mesons which stop in the emulsion are captured by the coulomb field of light nuclei, then it follows from reference 1 that the probability of a $\pi$ meson decay is $\sim 10^{-3}$. Beginning with the generally accepted value of the $\pi$ meson lifetime ( $\sim 10^{-8}$ sec ), we get a value of $\tau \sim 10^{-11}$ sec for the lifetime in relation to the nuclear capture of a $\pi$ meson from the $K$ shell of light nuclei. Meanwhile, theoretical estimates of $\tau$, even for hydrogen and deuterium, give $\sim 10^{-15} - 10^{-16}$ sec (see, for example, reference 3), whereas for C,N,O one can expect a decrease in $\tau$ by several orders of magnitude[4,5].

Thus, the problem of verifying and refining the observations[1] becomes interesting in order to ascertain whether or not the above mentioned contradiction might not be explained by incorrect experimental data.

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*Note added in proof:* Investigations appeared very recently[6] which reveal the shift of $\pi$ meson $K$-levels in light mesonic atoms, indicating an effective repulsion of $\pi$ mesons by nuclei. The connection between these facts and the results in reference 1 are not excluded.

[1] W. Fry and R. George, Phys. Rev. **93**, 1427 (1954)

[2] M. I. Podgoretskii and I. L. Rosental', J. Exper. Theoret. Phys. USSR **27**, 129 (1954)

[3] R. F. Marshak, Revs. Mod. Phys. **23**, 137 (1951)

[4] K. Aidzu, Y. Fujimoto, H. Fukuda, S. Hayakawa, K. Takayanagi, G. Takeda, Y. Yamaguchi, Progr. Theor. Phys. **5**, 931 (1950)

[5] J. Wheeler, Revs. Mod. Phys. **21**, 133 (1949)

[6] M. Stearns, et al, Phys. Rev. **96**, 804 (1954); **97**, 240 (1955)

Translated by H. Kruglak
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# Measurement of the Absorption Coefficient of High Energy Nuclear Interacting Particles

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At the present time the problem of the collision mechanism of high energy nuclear interacting particles is of considerable interest. The data on the elementary act of high energy particle interactions can be obtained by investigating the dependence of the absorption coefficient of such particles on their energy[1]. The pertinent measurements were made by us during fall of 1952 at two elevations: 3860 m (Pamir) and at sea level (Moscow) with identical hodoscopic setups.

In order to obtain a sufficient amount of statistical data for the registration of high energy nuclear interacting particles a detector of large area was used. Its cross section is shown in the Figure. A layer of lead $3 \times 2.5$ m$^2$ in area and 8 cm thick, supported on flooring covered with iron (total thickness $\sim 7$ gm/cm$^2$), was placed over a rectangular pit with a $2.5 \times 2$ m$^2$ bottom area and 2.5 m deep. Under this lead layer and at 30 cm from its lower surface another 2 cm lead layer was placed. These lead filters absorbed the electron-photon component of cosmic radiation incident on the apparatus from