with the observed $A^{\frac{2}{3}}$ variation of the meson production cross section, which extends even to light nuclei—a variation difficult to understand on the basis of the known mean free path for absorption of mesons.

Levinger's calculations could now be remade on the basis of the present model. The changes would be to replace his $\sin^2\theta$ angular distribution of the deuteron disintegration by an isotropic distribution and to change the absolute cross section and its variations with energy. All of these changes would be in the direction to bring his results in better conformity with experiment. The actual calculations should await accurate measurements of the deuteron disintegration, which should be forthcoming shortly. Occasionally three nucleons and a meson will be within the interaction volume. This will happen in nuclear matter about one-third of the time, but it too should be included in the calculation. The probability of re-emission of the meson from the two nucleon system increases roughly as the square of the energy, and hence, this process too becomes important at higher energies.

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The Condensation Phenomenon of an Ideal Einstein-Bose Gas

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THE well-known statistical conclusions concerning the "condensation phenomenon" of an ideal Einstein-Bose gas are not only of independent theoretical interest, but have gained additional importance through attempts to base on them explanations for the superfluidity effects observed with He II.[1]

The ideal E.-B. gas below the "condensation temperature" is looked upon as being composed of essentially two phases, both of which fill the accessible volume uniformly; one phase is thought to consist essentially of gas particles of zero energy, while the other behaves similarly to an E.-B. gas above the condensation temperature. The equilibrium shifts very rapidly in favor of the first-mentioned condensed phase if below the condensation temperature, density is increased or temperature lowered. To distinguish from ordinary condensation one talks about condensation in the momentum space.

A renewed investigation of these statistical results leads to a revision of some accepted views. It can be shown that by proper introduction of the energy levels occurring in an ideal gas one arrives, on account of the zero point energy, at a distribution law over the various states of momentum which is not the same as that given in reference 1. This, by itself, constitutes only a quantitative change which otherwise does not affect the general conclusions.

One encounters, on the other hand, essential modifications in the study of an ideal E.-B. gas in the earth's gravitational field, hereby approaching real conditions more closely. Again, we find a separation into two phases as described before. But now the condensed phase no longer occupies the total accessible volume; it is essentially confined to a very thin layer at the bottom of the vessel. To fix ideas: 2×10^{22} atoms of He, looked upon for the moment as constituting an ideal gas at 2°K and contained in a cube of 1 cm^3 volume, would form a film on the bottom about 10^{-3}-cm thick. Analytically, the ratio determining the "barometer formula" of the ideal condensed phase is no longer mgz/kT but mgz/ϵ_i, where ϵ_i denotes the energy of the quantum state under consideration; in the present case this will be essentially the zero point energy in the gravitational field.

The density of such an ideal "condensed" He gas reaches values of the order of 100 g/cm^3. Experience shows that liquid He is formed by the interatomic forces at densities of the order of 10^{-1} g/cm^3; the interatomic distance in the ideal "condensed" gas phase would be about as small as the Bohr radius of He. Obviously, such an ideal condensed gas could never be realized; long before the conditions for its existence are satisfied the interatomic forces will become predominant and make the gas strongly nonideal.

The ideal condensed gas is still described by eigenfunctions corresponding to the lowest momentum state in the plane perpendicular to the gravitational field. This condition obviously cannot be preserved in the presence of interatomic forces; how far it persists approximately can only be decided with the aid of a theory of the liquid state.

The difference in the behavior of He^3 and He^4 strongly suggests that E.-B. statistics play a fundamental roll as far as superfluidity is concerned. Still, care seems indicated in the use of analogies based on effects occurring in ideal E.-B. gases, since the interatomic forces apparently influence the phenomena qualitatively.

A more detailed paper will follow.

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The Photodissociation of the Helium Nucleus by High Energy Gamma-Rays

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THE photodissociation of alpha-particles by high energy synchrotron gamma-rays of a maximum energy of 320 Mev was studied by the previously reported[1] method used in the study of the photodissociation of the deuteron. The analysis was made on the proton tracks found in photographic emulsion exposed to the secondary particles emitted from a gas target of helium. The exposure had been made originally by Jakobsen *et al.*,[2] to investigate the photomeson production in the helium nucleus. Because of the fairly large experimental error, the conclusions are not entirely free from ambiguities. It seems, however, difficult to get more accurate results before the intensity of the synchrotron beam

Table I. Energy spectra of the protons in the photodissociation of the deuteron and the α-particle, at emission angles of 45°, 90°, and 135°.

	Energy (Mev)	Deuteron	α-particle		Energy (Mev)	Deuteron	α-particle
45°	78		26.2±2.9	90°	68		11.7±1.7
	80	18.7±1.7			72	5.2±0.8	
	87	15.6±1.6			80	4.1±0.8	
	93	9.0±1.4	17.7±2.0		86	3.9±0.8	7.3±1.1
	99	12.3±2.5			93	4.8±1.0	
	103	8.6±1.5	17.4±2.1		99	6.3±1.3	9.0±1.6
	116	6.8±1.2			108	5.9±1.6	6.5±1.2
	126	7.3±1.3			117	5.7±1.7	6.0±1.3
	141	5.8±1.3			125	3.7±1.4	
	154		6.4±1.3		132	2.4±1.2	3.9±0.9
	165		5.5±1.4		143	2.1±0.7	
	177	6.7±1.6			161	0.67±0.47	
	189	8.5±1.6			172		1.3±0.4
	205	3.5±1.8	6.4±1.4		182	1.2±0.7	
	216	2.3±1.6	2.8±1.2	135°	84		4.5±0.9
	241		3.3±1.5		86	3.7±0.8	3.5±0.8
	258		1.9±1.1		92	3.4±0.8	3.5±0.8
	320	2.6±1.1			98	2.7±0.8	5.6±1.0
					103	2.8±0.9	3.6±1.2
					116	0.6±0.4	2.9±0.8
					122		2.2±0.7
					127		1.6±0.6
					134		1.3±0.6
					140	1.7±0.7	1.1±0.4

is improved considerably. Therefore, it was considered worthwhile to present the results in spite of their lack of completeness.

The energy spectra of the protons at the emission angles of 45°, 90°, and 135° are shown in Table I together with the previously reported[1] data for the deuteron. The values are corrected for the nuclear absorption of protons in the absorbing material. To make the numbers comparable in the deuteron and alpha-particle cases, they are normalized to the number of protons in the nucleus concerned. The data available in the helium case are less complete than those in the deuteron case.

In the 45° case, there seems to be a fairly well-defined cutoff at energy almost equal to the cutoff energy of the deuteron, which is approximately 200 Mev. The yield corresponding to a proton energy of about 160 Mev is nearly equal in both cases. In the case of helium, the yield of protons below 140 Mev increases more steeply with decreasing energy than in the case of the deuteron, indicating the existence of more low energy protons.

In the 90° case, the cutoff energy is again nearly the same in both cases. The energy distribution curve below the cutoff energy in the helium case shows a steady increase of the number of protons with decreasing energy, leaving no plateau below the cutoff, indicating again the larger number of protons below about 140 Mev.

In the 135° case, the energy spectrum extends up to about 130 Mev, which is higher than the cutoff energy of the deuteron case.

The conclusions one can draw from these data might be as follows. The fact that the cutoff energies of the spectra of protons at 45° and 90° are approximately the same as in the case of the deuteron, seems to indicate that the high energy protons, at least in the 45° case, are produced by the absorption of a photon in a two-nucleon system. The existence of protons of energy higher than the cutoff energy of the deuteron in the 135° case might be due to an absorption process in which the energy and momentum of a photon is taken up by three or four nucleons. The fact that there are more protons below, say, 140 Mev at the emission angles of 45° and 90° in the helium case than in the deuterium case, might also be explained by the three- or four-nucleon process mentioned above. The lack of protons above the cutoff energy for the two-nucleon process in the 45° and 90° cases and the lack of protons of energy above about 130 Mev in the 135° case, seem to indicate that the cross section for a process such as $He+\gamma\rightarrow T+p$ is small compared to the two-nucleon process. They also indicate the small probability for a process such as $He+\gamma\rightarrow 2p+2n$ or $He+\gamma\rightarrow D+p+n$, in which the proton gets more energy than allowed by the two-nucleon process.

The present results, together with the previous results on the deuteron, should help to provide a fundamental basis for interpreting the photodissociation of nuclei in general by high energy gamma-rays.

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V^0 Particles and Isotopic Spin*

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RECENT experiments and interpretations on the scattering of mesons by protons[1,2] have suggested that the isotopic spin T is a good quantum number for meson-nucleon systems. It is therefore of interest to consider the implications of this quantum number for the unstable cosmic-ray particles. As an example the V^0 will be considered as a nucleon in an excited state, a generic term that includes any heavy fermion. Similar considerations are applicable to bosons without essential novelty.

The most remarkable feature of the V^0 particle is its stability against decay by π- and γ-emission. As a first approximation, we inquire under what conditions it could be absolutely stable. Let $\mathbf{t}$, $\boldsymbol{\tau}$, and $\mathbf{T}$ be the respective isotopic spin vectors of the nucleon, π-meson, and total system. The interaction energy is $H_0\sim(\mathbf{t}\cdot\boldsymbol{\tau})$, with corresponding selections rules for single meson emission

$$\Delta t,\ \Delta t_z=0,\ \pm1, \tag{1a}$$

$$\Delta T,\ \Delta T_z=0. \tag{1b}$$

The emission of a real meson requires at least 140 Mev, so that by (1) an excited nucleon will be stable against π-decay to its ground state ($t=\frac{1}{2}$) if its excitation energy E and isotopic spin satisfy the relation

$$E<(t-\tfrac{1}{2})\ 140\ \text{Mev}. \tag{2}$$

Since the V^0 ultimately emits one π-meson, it must have $E>140$ Mev, which is charge forbidden only if $t>\frac{3}{2}$. The simplest choice is $t=5/2$, $140<E\lesssim280$ Mev, with an eventual Q value for π-emission of $0<Q\lesssim140$ Mev. There is of course no difficulty about the production of states with large t values in a high energy nuclear event where many particles are present in strong interaction.

This stability against π-emission is independent of the magnitude of H_0, which is not true of the stability against γ-emission. In the isotopic spin formalism the photon interaction term is of the form $H\sim a+bt'$, where t' is the isotopic spin of whatever particle is involved. The selection rule accordingly depends on whether the V^0 is in a single-nucleon state or a virtual state of nucleon plus meson,

$$\text{single}-\text{nucleon}\quad H_\gamma\sim A+BT_z,\quad \Delta T=\Delta T_z=0 \tag{3a}$$

$$\text{nucleon}+\text{meson}\quad H_\gamma\sim a+\alpha+bt_z+\beta\tau_z,\quad \Delta T_z=0,\ \Delta T=0,\ \pm1. \tag{3b}$$

The rule (3b) requires $b\neq\beta$, which is generally true; it is this type of process that occurs in the decay of a π^0 meson ($T=1$) into two photons, each of isotopic spin $T=0$.

If isotopic spin is to be made the basis of γ-stability, (3a) indicates that the V^0 must have $t>\frac{1}{2}$. On the other hand, (3b) shows that the V^0 must also be stable against virtual π-meson emission, for otherwise it could decay rapidly by emitting $(t-\frac{3}{2})$ photons and one π. Thus isotopic spin considerations alone cannot account for both π- and γ-stability but only for one of the two: If γ-emission can be "turned off," π-stability can be achieved, or if some external postulate ($g^2/\hbar c\sim10^{-12}$) is introduced to give π-stability, isotopic spin restrictions can provide equally good γ-stability without additional assumptions.

Therefore, if isotopic spin is to help account for V^0 stability, a model must be chosen in which $t\geq\frac{3}{2}$ for the V^0. This would imply the existence of a number of companion particles, including at least V^- and V^{++}, which decay in a similar fashion to $n+\pi^-$ and $p+\pi^+$. The V^+ particles would exist for any value of t, and their modes of decay should provide some information on t of the initial state. For $\pi-V$ coupling of the type H_0 the relative frequencies of decay $(V^+\rightarrow n+\pi^+):(V^+\rightarrow p+\pi^0)=2:1$ or $1:2$ according as $t=\frac{1}{2}$ or $\frac{3}{2}$. For higher values of t, $(t-\frac{3}{2})$ quanta must accompany the π-decay if the $\pi-V$ coupling is of type H_0; if it is of type H_γ, the decay will divide in comparable proportion among processes accompanied by $(t-\frac{1}{2})$, $(t-\frac{3}{2})$, $(t-5/2)$ quanta. The decay lifetime increases by order $1/\alpha\sim10^2$ per quantum.

Thus the following conclusions are reached: The apparent failure to observe V^{++} and other companion particles with frequencies comparable to V^0 suggests that the V-particle wave functions have some (or all, if T is a good quantum number) components with $t<\frac{3}{2}$. This would mean that independent principles must be found to explain both the π- and γ-stability of these particles without help from isotopic spin considerations, which could have eliminated one type of instability. A direct check of t for the V^+ particles is in principle possible from a determination of the $(n+\pi^+):(p+\pi^0)$ ratio. The presence of V^- particles in the face