TABLE I. Electrical properties of $Na_{0.55}WO_3$ and normal metallic Na. Corrected values for the bronze are based on the actual atomic density of Na in WO_3.

	Resistivity 10^6 ohm-cm	Temp. coeff. of res. 10^8 ohm-cm/°C	Hall coeff. 10^4 cm³/coul.	Magn. susc. 10^6 cgs
Measured (indicated x)	5.3 (0.55)	15.7 (0.55)	−5.1 (0.66)	0.20 (0.65)
Adjusted (to $x=0.55$)	5.3	15.7	−6.1	0.19
Corrected	0.80	2.4	−2.2	0.53
Pure Na	0.52	2.3	−2.5	0.63

In an elementary way the sodium can be thought of as distributed in a cubic framework of tubes of uniform diameter. If α is the fraction of the total volume which is conducting, the ratio of the resistivity of the conducting material to the measured resistivity is slightly larger than $\alpha/3$ (using the exact relation between cross-sectional and volume fraction for a cubic mesh), while the true and measured Hall coefficients differ by a factor α. Table I lists the measured and corrected values of these quantities ($\alpha=0.36$) and compares them with those of sodium metal (25°C). Wherever necessary, the measured values have been adjusted to the normal density ($x=0.55$) by free electron gas density corrections. Values for the original x and after this adjustment are listed.

The table includes the temperature independent magnetic susceptibility measured by Stubbin and Mellor. It should be noted that the distance between neighboring sodium sites in the bronze lattice (3.80A) is very close to the nearest neighbor distance in metallic sodium, and that at the concentration of interest 0.82 of all sites in one direction are occupied. Thus, both the volume available to the sodium and the nearest neighbor distance in the bronze are comparable to those in the bulk metal.

I would like to thank Dr. Banks for a valuable discussion on the properties of these bronzes.

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Photodisintegration by Meson Reabsorption

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THE production of high energy protons when synchrotron bremsstrahlung are incident on nuclei has been measured by Silverman and Leventhal[1] and by Keck[2] using counters, and by Walker,[3] Miller,[4] and Kikuchi,[5] using photographic techniques. It is observed that the high energy protons are strongly peaked in the forward direction, that the cross section is nearly proportional to Z, that the energy of the protons cuts off at about half the photon energy and that the cross sections are large, i.e., about $Z\times10^{-28}$ cm² per "Q" for protons above 70 Mev produced by 300-Mev bremsstrahlung.

Levinger[6] was able to show fair agreement with the angular distribution assuming an electromagnetic interaction of the photon with two closely interacting nucleons, i.e., a "deuteron," in the nucleus. Basic to his theory were the calculations of Schiff on the disintegration of the deuteron. On the other hand, Levinger's theory gave too low values for the absolute cross section. Kikuchi and Miller measured the number of stars as a function of photon energy. The remarkable increase in the cross section beginning at the meson threshold led them to suggest meson emission and reabsorption in the same nucleus as the mechanism of the disintegration. An objection to this picture was raised, however, because it would predict a more nearly isotropic distribution of the protons inasmuch as the mesons are formed principally at large angles. Kikuchi pointed out that most of the high energy protons were associated with stars and that the absolute cross section was consistent with the assumption of meson emission and reabsorption. Thus, this theory explains the large cross section but fails to explain the angular distribution, while Levinger's theory explains the angular distribution but not the cross section.

The discrepancy between the two theories is resolved if the emitted meson is reabsorbed by the system consisting of the parent nucleon and its nearest neighbor. These two nucleons will usually be a neutron and a proton, in which case the meson production and reabsorption will be indistinguishable from the electromagnetic deuteron disintegration process. The system will retain the momentum of the photon, so that the angular distribution will now be given essentially by Levinger's calculation.

We must now show that most of the mesons are reabsorbed by the parent nucleons. Consider first the case of a deuteron. One can assume, after Fermi,[8] that if the two nucleons and the meson are all produced within a volume of radius $\hbar/\mu c$, then they will all interact and come into equilibrium so that the resulting particles will be given by their statistical weights. The most probable result will be the emission from the system of just two nucleons, the probability of re-emission of the meson being ten percent or smaller. Thus, the above process will look exactly like the photoelectric disintegration of the deuteron. From the known wave function of the deuteron, one can calculate the probability of the two nucleons being within a radius of $\hbar/\mu c$. This is roughly 0.2 for the Hulthén wave function. Then, if the meson is also within this radius at the time of production, as it is at these high energies (meson energy >70 Mev), we need take roughly 0.2 times the known meson production cross section for the neutron and proton to find the cross section for photodisintegration of the deuteron. For 300-Mev photons, the total charged and neutral meson production cross section per nucleon is about $2.\times10^{-28}$ cm², and hence, the photodisintegration cross section at this energy should be about 0.8×10^{-28} cm²—more than an order of magnitude greater than Schiff's extrapolated values would indicate. Except for the effects of virtual mesons, the cross section should parallel the variation of the meson production cross section with energy. Benedict,[9] Kikuchi,[10] and Gilbert[11] have observed anomalously large cross sections, as this treatment would indicate.

One could sharpen the above argument considerably using detailed balancing to determine the probability of reabsorption, but this has not been done because it is felt that virtual mesons will also contribute considerably to the cross section, especially for photon energies near meson threshold. It is difficult in the above process of meson production and reabsorption to see how the nucleons can tell the difference between a meson that is to be real or one that is virtual. Roughly speaking, meson production can be considered in two stages—as are nuclear reactions. First, the photon is absorbed to form an "excited nucleon," which then decays by meson emission or alternatively by re-emission of the photon depending on the available energy, statistical weights, etc. The excited nucleon may consist of a virtually produced meson raised to a different energy state. Then, presumably, this meson is available to be absorbed by the two nucleon system exactly as was discussed above for real mesons. Thus, we would expect the "meson part" of the photodisintegration cross section to parallel the cross section for formation of the excited nucleon and to extend even below the meson threshold.

Now in nuclear matter the probability of a given nucleon having a neighboring nucleon with $\hbar/\mu c$ is much greater than in the simple deuteron. In fact, since the average spacing between nucleons is about $\hbar/\mu c$, the probability will be close to unity. This means that mesons are not essentially produced in the interior of the nucleus, for most of the mesons are reabsorbed directly on production. Furthermore, those mesons which leave the nucleons must have been produced at the surface. This is in agreement 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
45°	78		26.2±2.9
	80	18.7±1.7	
	87	15.6±1.6	
	93	9.0±1.4	17.7±2.0
	99	12.3±2.5	
	103	8.6±1.5	17.4±2.1
	116	6.8±1.2	
	126	7.3±1.3	
	141	5.8±1.3	
	154		6.4±1.3
	165		5.5±1.4
	177	6.7±1.6	
	189	8.5±1.6	
	205	3.5±1.8	6.4±1.4
	216	2.3±1.6	2.8±1.2
	241		3.3±1.5
	258		1.9±1.1
	320	2.6±1.1	

	Energy (Mev)	Deuteron	α-particle
90°	68		11.7±1.7
	72	5.2±0.8	
	80	4.1±0.8	
	86	3.9±0.8	7.3±1.1
	93	4.8±1.0	
	99	6.3±1.3	9.0±1.6
	108	5.9±1.6	6.5±1.2
	117	5.7±1.7	6.0±1.3
	125	3.7±1.4	
	132	2.4±1.2	3.9±0.9
	143	2.1±0.7	
	161	0.67±0.47	
	172		1.3±0.4
	182	1.2±0.7	
135°	84		4.5±0.9
	86	3.7±0.8	3.5±0.8
	92	3.4±0.8	3.5±0.8
	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