LETTERS TO THE EDITOR

Prompt publication of brief reports of important discoveries in physics may be secured by addressing them to this department. Closing dates for this department are, for the first issue of the month, the eighteenth of the preceding month, for the second issue, the third of the month. Because of the late closing dates for the section no proof can be shown to authors. The Board of Editors does not hold itself responsible for the opinions expressed by the correspondents.

Communications should not in general exceed 600 words in length.

The Outer, Initial Permeability of Nickel from 10 to 70 Megacycles

High frequency currents may be measured with accuracy by passing them through a fine straight filament sealed in a vacuum and observing the luminosity of the filament by means of an optical pyrometer. Calibration with direct current may be made, provided the wire is fine enough that the square root of the ratio of its high frequency to its d.c. resistance is not greater than the desired accuracy.

By means of a Fleming differential calorimeter, the rate of heat production in a sample of wire heated by high frequency current I may be balanced against that produced by direct current in a similar sample. Then, the skin effect coefficient, $S=R/R_0=(I_0/I)^2$, may be calculated and used in the skin effect equation, $\mu_r=S^2\rho/\pi^2a^2f$, to compute the "outer" permeability μ_r of the wire sample at very high frequencies. The resistivity is ρ, while f is the frequency, and a is the radius of the wire.

Experimental values of S for a nonmagnetic sample (copper) were found to agree very well with the theoretical values from 10 to 70 megacycles per second. Values of μ_r for a No. 18 nickel wire were then determined over the same frequency range. As shown in Table I they decrease with increasing frequency.

TABLE I. *Values of the outer permeability μ_r at various frequencies.*

f, *Mc*	9.59	10.1	11.6	14.1	16.6	22.9
μ_r	13.3	13.8	13.3	14.2	12.1	10.2
f, *Mc*	27.7	31.6	40.0	46.2	53.6	69.8
μ_r	11.4	9.7	8.8	9.0	7.9	5.9

J. BARTON HOAG
J. L. GLATHART

Ryerson Physical Laboratory,
University of Chicago,
Chicago, Illinois,
January 8, 1940.

Erratum: The Radioactivity of Mn^{56}

(Phys. Rev. **56**, 1168 (1939))

The energy groups referred to in the second sentence of the letter were actually plotted as momentum groups. All through the letter mc^2 should read mc.

R. H. BACON
E. N. GRISEWOOD
C. W. VAN DER MERWE

Department of Physics,
New York University,
Washington Square College,
New York, New York,
January 6, 1940.

The Use of Radioactive Isotopes of the Common Elements in Physiology

In these columns[1] doubt was expressed recently as to the validity of conclusions drawn from the use of radioactive isotopes in physiology on the ground of the destructive effect of the radiation emitted by these isotopes. There was especial objection raised to the conclusion arrived at from work with radioactive sodium,[2] that sodium ions penetrate through the red cell membrane, since the radiation emitted by radio-sodium might denature the proteins. This objection seems, however, not to be justified if the use of preparations of high activity is avoided. This is best shown by the fact that the investigation of the permeability of red cells to potassium ions[3] leads to the result that the bulk of the potassium ions present in the corpuscles does not exchange with those present in the plasma. The radiation emitted by K^{42} in the last-mentioned experiments had about the same intensity and the same hardness as that emitted in the corresponding experiments with Na^{24}. If the effect of the radiation on the cell wall would suffice to make the latter permeable to ions, it would be difficult to explain why potassium does not escape from the corpuscles in contrast to sodium. Furthermore, we have to envisage that the animal body contains quite an appreciable amount of "natural" potassium which emits β-radiation of hardness similar to many of the artificially produced radioelements. If we stress the importance of the noxious effect of the radiation emitted by the radioactive indicator, we arrive at the result that every organism, owing to the presence of potassium, is always under the influence of such an effect; in point of fact research carried out by using activities of K^{42} of the same order of magnitude as that of the potassium normally present in the animal leads to the same result as that in which many times that amount was used. It is important, when discussing the possible disturbing effect of the radiation, to envisage that the method of radioactive indicators is not based on atoms disintegrating and thus emitting radiation in the animal, but on the faculty of some of the atoms of the indicator extracted from the tissues, for example, to emit radiation when placed under the Geiger counter or another measuring instrument. When a Na^{24} atom happens to disintegrate inside the body, it is transformed into a magnesium atom and can, therefore, no longer be used as an indicator of sodium metabolism. The number of Na^{24} atoms disintegrating inside the body must, of course, be kept so low that they cannot produce a noxious action on the tissues. In some of our experiments on the permeability of the corpuscles to sodium the

circulation contained 10^8 Na^{24} atoms; thus, the number of radio-sodium atoms was only 1/1000 of that of the corpuscles of the rabbit and less than 1/10 of these atoms disintegrated in the circulation during the experiment.

Isotopes, radioactive and nonradioactive ones as well, are not strictly chemically identical and this may become a source of error in certain cases; furthermore, the problem of the permeability of the corpuscles to sodium is not yet finally settled for reasons the discussion of which would lead too far. The objection raised against the use of radioactive indicators in elucidating the above problem based on the possible effect of the radiation on the red cell walls seems to us, however, not to be justified.

G. HEVESY

Institute of Theoretical Physics,
Copenhagen, Denmark,
December 14, 1939.

[1] A. Barnett, Phys. Rev. **56**, 963 (1939).
[2] W. E. Cohn and E. T. Cohn, Proc. Soc. Exp. Biol. and Med. **45**, 445 (1939).
[3] L. Hahn, G. Hevesy and O. Rebbe, Biochem. J. **23**, 1549 (1939).

Energy and Half-Life of Be^{10}

Recent precision determinations[1] of the maximum energy of the charged particles emitted in light nuclear reactions have led to the values 9.01474 and 10.01579 for the masses of Be^9 and B^{10}, respectively. On bombarding beryllium with 3.1-Mev deuterons a yield of protons of range 52.6 cm was found corresponding to an energy change of 4.52 Mev in the reaction

$$Be^9+D\rightarrow Be^{10}+H.$$

This is in good agreement with Oliphant, Kempton and Rutherford[2] who found the value 4.59 Mev. The deduced mass for Be^{10} is 10.0165 ± 0.0001. The energy difference between Be^{10} and B^{10} is therefore approximately 0.67 Mev.

The electrons from Be^{10} were discovered by McMillan[3] who states in a brief report that their upper limit is about 0.3 Mev and half-life greater than 10 years. A beryllium probe which had been bombarded by deuterons for approximately 60 microampere hours after three weeks' aging showed a definite activity whose absorption curve indicates a range of 0.25 ± 0.03 g/cm^2 in aluminum which, by Feather's empirical formula corresponds to 0.75 ± 0.07 Mev for the upper limit, which agrees reasonably well with the masses given above. The half-life can be estimated roughly from the yield: It was found that 4×10^6 protons per microampere per minute were evolved in all directions so that the sample of Be^{10} contained 1.4×10^{10} radioactive atoms. The total number of electrons evolved is estimated to be 8 per second from which the decay constant can be deduced to be 5.7×10^{-10} sec.$^{-1}$ giving a half-life of 380 years.

I wish to thank Dr. Gordon Brubaker for the amplifier used for detection and Mr. W. L. Davidson, Jr., for help in running the cyclotron.

ERNEST POLLARD

Sloane Physics Laboratory,
Yale University,
New Haven, Connecticut,
January 2, 1940.

[1] S. K. Allison, E. R. Graves, Lester S. Skaggs and N. M. Smith, Jr., Phys. Rev. **55**, 107 (1939); S. K. Allison, Phys. Rev. **55**, 624 (1939).
[2] M. L. Oliphant, E. Kempton and Rutherford, Proc. Roy. Soc. **150**, 241 (1935).
[3] E. McMillan, Phys. Rev. **49**, 875 (1936).

On Bose-Einstein Fluids

It has been suggested by London[1] that the two liquid modifications of helium, below and above its transition temperature, might correspond qualitatively to the two phases predicted by Einstein[2] for an ideal gas which follows the laws of the Bose statistics. We should like to discuss here the properties of elasticity of such a Bose-Einstein (B-E), fluid as their experimental study might furnish supplementary information concerning the eventual quantum-statistical interpretation of the transition in liquid helium.

The average intensity of light scattered by a given volume of a fluid is, as well known, proportional to $\langle\Delta N^2\rangle_{Av}/N^2$ or $\langle\Delta V^2\rangle_{Av}/V^2$ i.e., to the relative mean square fluctuations of the total number N of the particles of the fluid, or its volume V, around the equilibrium value at a given temperature T. Now, one may write

$$\langle\Delta N^2\rangle_{Av}/N^2=\langle\Delta V^2\rangle_{Av}/V^2=kT\chi_T/V,$$

where k is Boltzmann's constant and χ_T is the isothermal compressibility of the fluid at temperature T. For an ideal B-E fluid χ_T tends to infinity when the temperature is decreased to the quantum-condensation temperature T_0 of the fluid. Consequently, if this condensation takes place in coordinate space, as the condensation of ordinary fluids, then a B-E ideal fluid scattering light should become opalescent when its temperature approaches T_0 from the high temperature side. If, however, the condensation takes place only in impulse space, the condensed particles do not separate themselves in space from the other particles of the fluid, the elementary scattering volumes of the fluid do not suffer any abnormal spatial change, and in spite of the anomalous isothermal compressibility predicted by the statistical thermodynamics of the fluid, no quantum opalescence should exist near T_0. The apparent ambiguity in the interpretation of the fluctuational properties of an ideal B-E fluid seems to indicate that the usual statistical thermodynamics of such a fluid does not give an adequate account of its quantum condensation.

In the case of a nonideal B-E fluid where the nonideal character is taken into account by an average potential energy U, independent of the coordinates of the particles, smeared over the whole volume of the fluid, the pressure is

$$p=p_{id}-(\partial U/\partial V).$$

where p_{id} is the pressure of the ideal fluid and now χ_T becomes almost normal around T_0. This, incidentally, is the same as for the ideal fluid, as there is no apparent reason for $\partial U/\partial V$ having an anomalous behavior around T_0. The sudden vanishing of $\partial p_{id}/\partial V$ near T_0 causes a slight jump in χ_T from $V^{-1}(-\partial p_{id}/\partial V+\partial^2 U/\partial V^2)^{-1}$ at a temperature slightly higher than T_0 to $V^{-1}(\partial^2 U/\partial V^2)^{-1}$ at T_0, and in the case of condensation in coordinate space the scattering of light might be slightly abnormal around T_0. Again, following the mechanism of condensation in impulse space no such anomaly should exist.

The adiabatic compressibility of an ideal B-E fluid χ_{ad} given by the quotient of χ_T and the ratio c_p/c_v of the specific heats may be considered as normal around T_0, and it will be so *a fortiori* for a nonideal fluid. Apparently this