it. After six days of continuous operation a 10-cc sample was removed from the top end of the column. This sample, which contains the light (HCl^{35}) fraction,[1] was dissolved in water and was activated, together with another solution containing an identical amount of ordinary HCl, with the paraffin-slowed neutrons formed by the bombardment of beryllium with 45 microampere-hours of 16-Mev deuterons in the 60-inch cyclotron of the Crocker Radiation Laboratory. The chloride in these solutions was precipitated as silver chloride and the radioactivity in these precipitates measured with a Lauritsen electroscope. The sample of the enriched HCl^{35} from the top of the column showed a 37-minute activity with an intensity which was only one-fifth as great as that in the sample from ordinary HCl. Bombardment of the silver chloride precipitates, as a confirmatory experiment, gave the same result. The lower intensity in the HCl^{35} sample shows that this activity is to be assigned to Cl^{38}, formed as the result of neutron absorption by the heavier isotope Cl^{37}; the intensities of the radioactivities in the two HCl samples show that the enriched sample contained about 95 percent HCl^{35}.

It is known[7] that chlorine has a larger cross section for the absorption of slow neutrons than can be accounted for by the formation of the 37-minute activity alone and Grahame,[8] in a search for a second neutron-capture activity in chlorine, showed that there is no short-lived isotope. Grahame and Walke[9] have now shown that a very long-lived chlorine is formed as the result of deuteron or neutron bombardment of chlorine. This activity, which undergoes decay by K-electron capture as well as by positron and negative beta-particle emission, is to be assigned to Cl^{36} and removes the anomaly in the slow neutron absorption cross section of chlorine.

The definite assignment of the 37-minute activity to Cl^{38} makes it likely that the high energy (5 Mev) group of beta-particles, originally reported[10] to be associated with A^{41} but shown by Davidson[11] to be inconsistent with mass data, are actually due to Cl^{38} formed in the reaction $A^{40}(d, \alpha)Cl^{38}$. A small amount of Cl^{38} would have been present with the A^{41} in the procedure used in the original energy determination.[10]

We wish to thank Professor Ernest O. Lawrence for his interest in this work and we are grateful to the Research Corporation for financial assistance.

J. W. Kennedy
G. T. Seaborg

Department of Chemistry,
University of California,
Berkeley, California,
April 16, 1940.

[1] K. Clusius and G. Dickel, Zeits. f. physik. Chemie **B44**, 397 (1939); Naturwiss. **26**, 546 (1938).
[2] E. Amaldi, O. D'Agostino, E. Fermi, B. Pontecorvo, F. Rasetti and E. Segrè, Proc. Roy. Soc. **A149**, 522 (1935).
[3] S. N. Van Voorhis, Phys. Rev. **49**, 889 (1936).
[4] D. Hurst and H. Walke, Phys. Rev. **51**, 1033 (1937).
[5] W. Bothe and W. Gentner, Zeits. f. Physik **112**, 45 (1939).
[6] M. L. Pool, J. M. Cork and R. L. Thornton, Phys. Rev. **52**, 239 (1937).
[7] S. Kikuchi, E. Takeda and J. Ito, Proc. Phys.-Math. Soc. Japan **19**, 43 (1937).
[8] D. C. Grahame, Phys. Rev. **54**, 972 (1938).
[9] D. C. Grahame and H. Walke, private communication.
[10] F. N. D. Kurie, J. R. Richardson and H. C. Paxton, Phys. Rev. **49**, 368 (1936).
[11] W. L. Davidson, Jr., Phys. Rev. **57**, 244 (1940).

Scattering of Light by Liquid Helium

Although London's theory[1, 2] of liquid helium is able to account qualitatively for many of its properties in terms of a Bose-Einstein gas of helium atoms, it cannot be regarded as definitive, and it is of interest to consider other consequences of the theory for possible comparison with experiment. The density fluctuations and intensity of scattered light have recently been discussed in this connection by Goldstein.[3] Since this discussion makes essential use of inconclusive arguments connecting the condensation in coordinate and in momentum space, it seems desirable to give here the results of a detailed calculation.

Heisenberg[4] has used the formalism of quantized waves to calculate the energy fluctuations in a gas of light quanta obeying Bose-Einstein statistics. We have made an analogous calculation of the expectation value of the intensity of light of wave-length λ scattered by a small (spherical) volume $v \gg \lambda^3$, using Born approximation for the light waves. We use London's energy spectrum for the states of the independent atoms: $g(E)dE \propto E^{\sigma-1}dE$, where a fraction, γ, of all the atoms is supposed to be free to take part in the condensation process. The calculation is then straightforward if the wave-functions for the independent atom states are known. We assume them to be Bloch-type functions, having roughly the orthonormality properties of plane waves, and distributed in the space of the propagation vector $\mathbf{k}$ with density: $g(E)dE \propto k^2dk$. This is certainly true for the free-atom case[1] ($\sigma = \frac{3}{2}$, $\gamma = 1$), and appears to be the most reasonable interpretation of London's formalism for the other cases.[2] We then obtain for the ratio R of the intensity of light scattered per unit solid angle at 90° to the intensity of the incident unpolarized light:

$$R = \frac{4\pi^2\gamma v}{\lambda} \frac{(\mu-1)^2}{(\rho\lambda^3)^{1-1/\sigma}} \frac{T}{T_0}\left[1-\left(\frac{T}{T_0}\right)^\sigma\right]\left[\frac{3\gamma}{2^{7/2}\pi\zeta(\sigma)\Gamma(\sigma+1)}\right]^{1/\sigma},$$

when the index of refraction μ is close to 1; ρ is the atomic density, and ζ is the Riemann ζ-function. For temperatures T equal to or slightly greater than the temperature T_0 of the lambda-point, R does not strictly vanish, but is smaller than the above by a factor of order $(\rho\lambda^3)^\alpha$, where $\alpha = 1-1/\sigma$ for $\sigma \leqq 2$, and $\alpha = 1/\sigma$ for $\sigma \geqq 2$. A similar calculation shows that the relative mean square fluctuation in the density of a small region containing n particles on the average is of order $n^{1/\sigma-1}$, for $T < T_0$.

For liquid helium ($T_0 = 2.19°K$) under its vapor pressure at 2.0°K, $\rho = 2.2 \times 10^{22}$, $\mu = 1.028$. For $\lambda = 4358A$, the free-atom model ($\sigma = \frac{3}{2}$, $\gamma = 1$) gives $R_1 = 5.6 \times 10^{-3}$ for a centimeter cube. This corresponds to the scattering found experimentally by Keesom[5] for ethylene 0.36°C above its critical point, and is far too large to have escaped observation. The present calculation must therefore be regarded as a further argument against London's first model.[1] The experimental specific heat curve is reproduced well[2] with $\sigma = 5$, $\gamma = 0.136$; this gives $R_2 = 2.0 \times 10^{-7}$, which is even smaller than for normal liquids ($R = 2.0 \times 10^{-6}$ for water under standard conditions), and would be difficult to measure.

The numerical value R_2 calculated on the basis of the independent atom model cannot be regarded as comparable with experiment, since it neglects the correlations between the positions of the atoms that would be expected to play a decisive role in the fluctuations. For comparison with experiment, it is probably correct to employ the usual formula[6] together with the experimentally observed isothermal compressibility;[7] these give $R_3 = 1.3 \times 10^{-10}$, a value that is practically unaffected by crossing the lambda-point. However, this is so small as to be quite unobservable experimentally. The large difference between R_2 and R_3 indicates the importance of correlations in the density fluctuations.

The writer is indebted to Professor J. R. Oppenheimer for several helpful discussions of this subject.

L. I. SCHIFF

Department of Physics,
University of California,
Berkeley, California,
April 10, 1940.

[1] F. London, Phys. Rev. **54**, 947 (1938).
[2] F. London, J. Phys. Chem. **43**, 49 (1939).
[3] L. Goldstein, Phys. Rev. **57**, 241, 457 (1940).
[4] W. Heisenberg, Ber. Math.-Phys. d. Sächs. Akad. (Leipzig) **83**, 3 (1931).
[5] W. H. Keesom, Ann. d. Physik **35**, 591 (1911).
[6] R. C. Tolman, *Principles of Statistical Mechanics* (Oxford, 1938), p. 647.
[7] J. Satterly, Rev. Mod. Phys. **8**, 347 (1936).

The Attainment of High Hydrostatic Pressures

In a two-stage cascaded pressure apparatus designed and built by the Geophysical Laboratory hydrostatic pressures were attained in the second inner pressure vessel as predicted from the hypothesis recently published.[1]

In the run made on March 21 with this apparatus a pressure in excess of 200,000 atmospheres was obtained in the second-stage cylinder; no attempt was made to go to higher pressures because this was the limit to which the gages would record. Owing to the jerky behavior of the apparatus with increasing pressure, piston displacement measurements were made only as pressure was released. These measurements indicated that sodium chloride was compressed in excess of 20 percent—perhaps nearer to 30 percent—by this pressure. As a measure of sensitivity the initial volume compressibility to 10,000 atmospheres was obtained as 4.2×10^{-6} which agrees very well with the accepted compressibility of sodium chloride. The Carboloy piston of the second stage was under such high internal stress after this cycle of operations that it shattered on receiving a slight jar.

The first-stage cylinder has two pistons actuated by two presses tied together. One of these pistons is used to develop the hydrostatic pressure in the first-stage cylinder and the second piston is used to force the inner piston down. In the pressure run described above the inner piston diameter was one-eighth inch and the length less than one-quarter inch. The first-stage pressure was about 18,000 atmospheres.

In another run in which the inner piston was made one-half inch long, for a longer stroke, and the first-stage pressure reduced to 15,500 atmospheres the inner piston shattered at about 135,000 atmospheres.

Grateful acknowledgment is made to Dr. J. A. Fleming and Dr. M. Tuve of the Department of Terrestrial Magnetism for their hearty stimulus and cooperation. To Professor F. Bitter of Massachusetts Institute of Technology and Professor P. W. Bridgman of Harvard, we are indebted for the discussions held with them concerning the project involving the use of very high hydrostatic pressures which was begun about a year ago. Our thanks are also due the Carboloy Corporation and others for their kindness in making available to us the necessary alloys and to Mr. F. Rowe who built the apparatus.

ROY W. GORANSON
E. A. JOHNSON

Geophysical Laboratory, (RWG)
Department of Terrestrial Magnetism, (EAJ),
Carnegie Institution of Washington,
Washington, D. C.,
April 18, 1940.

[1] Roy W. Goranson, J. Chem. Phys. **8**, 323 (1940). A condensed version of this paper was presented at the September, 1939, meeting of the International Union of Geodesy and Geophysics.