[2] K. E. Drangeid, M. C. Gutzwiller, R. Sommerhalder, and H. Thomas, Proceedings of the Symposium on the Electric and Magnetic Properties of Thin Metallic Layers, Louvain, September, 1961 (to be published).

[3] R. Sommerhalder and H. Thomas, Helv. Phys. Acta 34, 29 (1961) and 34, 265 (1961).

[4] H. L. Caswell, J. Appl. Phys. 32, 105 (1961).

[5] H. Kaden, Die elektromagnetische Schirmung in der Fernmeldeund Hochfrequenztechnik (Springer-Verlag, Berlin, 1950), p. 169.

[6] R. Jaggi and R. Sommerhalder, Helv. Phys. Acta 33, 1 (1960).

STRUCTURE OF THE γ FORM OF SOLID He^4†

A. F. Schuch and R. L. Mills
Los Alamos Scientific Laboratory, University of California, Los Alamos, New Mexico

(Received April 26, 1962)

In the course of measuring sound velocities in compressed He^4, Vignos and Fairbank[1] discovered a new solid phase (designated the γ phase), which occurred in a narrow crescent-shaped band just above melting pressures, between 1.45 and 1.78°K. They observed that the new γ phase had a larger molar volume and entropy than the adjacent α phase, which was known to have the hexagonal close-packed (hcp) structure. Reasoning by analogy with the case of solid He^3 which undergoes a similar transition,[2,3] they thought it likely that the new phase in He^4 was body-centered cubic (bcc). For solid He^3 the transition between the hcp and bcc structures produces a volume change, ΔV_{tr}, of ~0.12 cc/mole near the melting curve.[2] Assuming that the same structures apply to the new He^4 transition, Schuch[4] used the Pauling[5] relation between bond length and coordination number to derive $\Delta V_{tr} = 0.187$ cc/mole for He^4 at 28.9 atm and 1.723°K. This value agrees closely with recent accurate measurements[6] of ΔV_{tr} and provides evidence that the γ phase is bcc. Further indication for this structure comes from a sound velocity study[7] made on mixtures of He^3 and He^4. As the concentration of He^3 was raised from 0 to 100%, the P-T coordinates of the transition shifted smoothly upward to those known for the hcp-bcc transition in pure He^3. The present experiment was aimed at a direct determination of the structure of the He^4 γ phase by x-ray diffraction.

The very narrow pressure and temperature limits which define the γ phase of solid He^4 made it necessary to modify the cryostat and cell arrangement used previously.[8] The sample was contained in a Be cell (0.8-mm bore by 0.4-mm wall) which could be oscillated through an angle of forty degrees. The cell was surrounded at each end by a small container of liquid He which oscillated with the cell and which was kept supplied with liquid from the main stationary Dewar through flexible metal bellows. A copper radiation shield, soldered to the main He Dewar, surrounded the cell assembly. This shield had windows of 0.00035-in. thick Ni foil for transmitting and filtering the x rays. Surrounding it was another copper shield cooled to liquid N_2 temperature and equipped with thin (0.0003-in. thick) Al windows. A steel capillary filling tube was joined to the bottom end of the Be cell by a conical compression closure. The tube was coiled inside the He radiation shield to reduce thermal conduction to the cell. It was estimated that the portion of the Be cell exposed to x rays ran ~0.04K° warmer than the He bath. Pressure in the cell inlet capillary was measured to ±1 psi with a 0-1000 psi Heise gauge previously calibrated with a free-piston gauge. High-purity He was obtained from the Amarillo Station of the Bureau of Mines. It was further purified by passing it through a charcoal trap cooled with liquid N_2. The photographs were taken with a 4- × 5-inch flat plate camera placed 5 cm from the sample. The radiation used was Cu K_α filtered, as mentioned, and collimated by a 0.040-in. aperture.

The sample was usually prepared by maintaining He at a suitably high pressure in the cell during cooling, although solid could be formed by cooling first and then raising the pressure above the freezing point. As was the case with the earlier work on He^3 and He^4, the x-ray reflections were single spots and not continuous rings, indicating that the solid was present in the form of large crystals and not as a powder.

It was found that solid He^4 does indeed undergo a structure change in the region described by Vignos and Fairbank.[1] The diffraction spots from the hexagonal cell were replaced by a set which could be indexed as the 110 and 200 reflections from a cubic body-centered cell. With respect to the 110 reflections, those indexed as 200 were very weak. The average interplanar spacings, as determined from eleven photographs of helium at 1.73°K and 29.01 atm, are

$$d_{110} = 2.911 \pm 0.009 \text{ Å}$$

and

$$d_{200} = 2.053 \pm 0.005 \text{ Å}.$$

Upon assigning equal weight to each set of measurements, one obtains 4.11 Å as the length of the cell edge. This implies a molar volume of 20.91 cc which is in good agreement with the value 20.928 cc obtained from the recent *PVT* measurements of Grilly and Mills.[6]

Seven diffraction photographs were taken of He^4 in the hexagonal phase at the same temperature but at the higher pressure of 29.70 atm. Under these conditions the hexagonal cell axes were found to be $a = 3.650 \pm 0.012$ Å and $c = 5.945 \pm 0.014$ Å. The molar volume is 20.66 cc which is slightly lower than the 20.700 cc computed from the *PVT* measurements.[6] The gross difference in molar volume of the two different phases as determined by x rays is 0.25 cc. After correcting for the difference in pressure by taking 26×10^{-4} cc/atm as the average molar compressibility of the two solids,[6] one obtains 0.21 cc/mole for ΔV_{tr}. Within the experimental error this agrees with the directly measured value[6] of 0.191 cc and the value of 0.187 cc computed from Pauling's equation.[4]

This research will be continued with a cylindrical camera in an effort to obtain reflections at greater Bragg angles.

We wish to express our appreciation to Mr. Robert Chrisman and Mr. Earl McGowen for their excellent work in the construction of the equipment.

[†] Work performed under the auspices of the U. S. Atomic Energy Commission.

[1] J. H. Vignos and H. A. Fairbank, Phys. Rev. Letters 6, 265 (1961).

[2] E. R. Grilly and R. L. Mills, Ann. Phys. 8, 1 (1959).

[3] A. F. Schuch, E. R. Grilly, and R. L. Mills, Phys. Rev. 110, 775 (1958).

[4] A. F. Schuch, Nature 191, 591 (1961).

[5] L. Pauling, J. Am. Chem. Soc. 69, 542 (1947).

[6] E. R. Grilly and R. L. Mills, Ann. Phys. (to be published).

[7] J. H. Vignos and H. A. Fairbank, Bull. Am. Phys. Soc. 7, 77 (1962).

[8] R. L. Mills and A. F. Schuch, Phys. Rev. Letters 6, 263 (1961).

DISSOCIATIVE EXCITATION TRANSFER AND OPTICAL MASER OSCILLATION IN Ne-O_2 AND Ar-O_2 rf DISCHARGES

W. R. Bennett, Jr., W. L. Faust, R. A. McFarlane, and C. K. N. Patel
Bell Telephone Laboratories, Murray Hill, New Jersey

(Received May 7, 1962)

This Letter is intended as a summary of excitation studies conducted in low-pressure rf discharges containing noble gases with varying amounts of oxygen impurity. We have found that the dominant mechanisms by which radiative excited states of atomic oxygen are produced under these conditions involve quasi-resonant transfer of energy from noble gas metastables to repulsive, neutral excited states of the oxygen molecule. Application of these results to Ne-O_2 and Ar-O_2 mixtures has permitted continuous optical maser oscillation on the $3\,^3P_2$-$3\,^3S_1$ fine structure transition of atomic oxygen at 8446 Å. The success of these gas maser systems suggests that dissociative excitation transfer represents a more general method for obtaining population inversions in gas discharges than is possible with methods based on inelastic atom-atom collisions.[1] In systems of that type, a close energetic resonance discrepancy (≅ a few kT) is required for efficient transfer. With systems of the present type, there are usually a moderate number of repulsive states of the impurity molecule which encompass an energy range ≅1 or 2 eV at typical internuclear separations and which terminate in the same excited states of the dissociated impurity atoms. Hence, a close coincidence with the energy of the initial metastable carrier is not required and a greater number of possible systems may be expected.

A number of relevant energy levels are shown in Fig. 1. All have been defined in respect to the ground-state oxygen molecule. Only dissociation