CRYSTAL STRUCTURE AND DENSITY OF HELIUM UP TO 232 KBAR

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Because helium is found in great abundance and at high pressures in the Jovian planets, the knowledge of phase relations and density of helium at high pressures is essential to the modelling of planetary interior. Yet owing to the experimental difficulties, direct determination of helium phases had only been made at cryogenic temperatures and pressures below 10 kbars in the past. With the recent development of high-pressure diamond-anvil cell and synchrotron x-ray sources, we report single crystal x-ray diffraction data of helium at 300K up to 232 kbars.

Helium was compressed in a modified Merrill-Bassett type diamond cell designed for condensed-gas single-crystal x-ray diffraction(1). To overcome the problem of the extremely low diffraction intensity of helium due to the small sample volume (10 picoliters) and low atomic number (Z = 2), the experiment was done at a polychromatic wiggler beamline at Cornell High Energy Synchrotron Source (CHESS) With energy-dispersive technique. The pressures were calibrated by the x-ray excited ruby R-line fluorescence scale (2).

The crystal structure of helium between 156 and 232 kar was determined to be hexagonal-close-packed (hcp), in contrary to the general belief that it should be bcc or fcc. Seven diffraction maxima were observed and indexed in the classes of (101), (102), (110), and (112) of hcp. The c/a ratio is 1.633 which is ideal for hcp. The density changes from 1.013 gm/cc at 156 kbar to 1.168 gm/cc at 232 kbar, a 15% increase which is the largest of any material at these conditions.

The pressure-volume data of helium below 200 kbar agree well with a "soft" high pressure equation of state calculated on the basis of an exponential-six potential of Ross and Young (3). At higher pressure, the experimental result indicate that a still softer potential is required. A modified equation of state is therefore necessary for extrapolating to the conditions of the planetary interiors.

References: (1) Mao, H., and Bell, P. M. (1980, Carnegie Inst. Wash. Yearbook 79, p 409, (2) Mao, H., Xu, J., and Bell, P. M. (1986) J. Geophys. Res. 91, p 4673, (3) Ross, M., and Young, D. (1986) Physics Letters A, 118, p 463.