TEMPERATURE DEPENDENCE OF ISOTOPIC EFFECTS IN THE STRUCTURAL PROPERTIES OF HYDROGEN ISOTOPES

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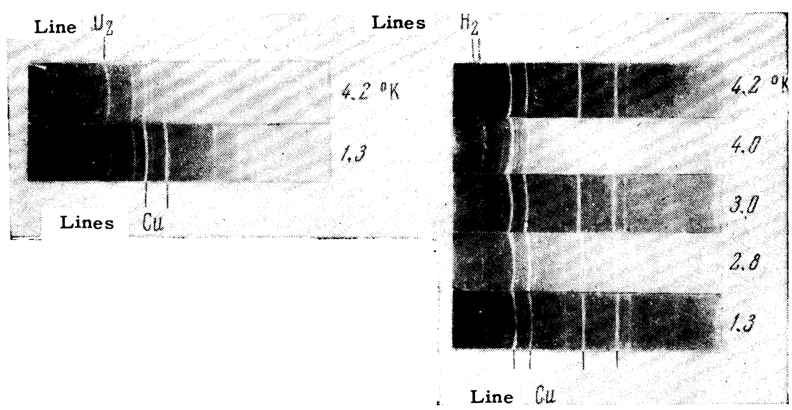
X-ray patterns of hydrogen isotope layers condensed on the lateral surface of a copper rod at various temperatures (between 1.3 and 4.2°K) are obtained. The deuterium x-ray patterns do not depend on the temperature and are the same as those of protium condensed below 2.8°K. However, the patterns of protium obtained by condensation at temperatures above 2.8°K exhibit a larger number of diffraction lines. The results are discussed from the viewpoint of the texture being dependent on the condensation temperature.

THE difference in the diffraction patterns of x-rays scattered by solid samples of hydrogen isotopes at 4.2°K has usually been interpreted as due to the presence of isotopic morphotropy [1]. Recently an attempt was made to attribute this difference to differences in the texture in the layers of protium and deuterium formed by condensation on a cold substrate [2]. This unique isotopic effect is apparently a derivative of the isotopic differences in thermodynamic characteristics of the hydrogen isotopes, such as the melting temperature or the equilibrium vapor tension at a given temperature. Consequently, from this point of view we can regard layers of protium and deuterium, which condense at a given substrate temperature, as layers of the same substance, but condensed at different effective temperatures.

In connection with the foregoing considerations, it is of interest to take x-ray photographs of solid hydrogen isotopes condensed on substrates of different temperatures. These photographs were obtained with an instrument previously described [1]. The temperature of the substrate (copper capillary filled with liquid helium) was varied from 4.2 to 1.3°K. The x-ray patterns of solid protium and deuterium samples condensed at different temperatures are shown in the figure. As can be seen from these pictures, the character of the diffraction pattern obtained from deuterium samples remains the same as the substrate temperature is changed from 4.2 to 1.3°K. On the other hand, the character of the diffraction pattern from samples of solid protium condensed in the same temperature interval depends on the substrate temperature. Lowering of the substrate temperature below 4.2°K leads to the appearance of a weak third (middle) line on the x-ray patterns of the solid protium; the intensity of this line increases with decreasing condensation temperature. At T ~ 3.5°K the new (middle) line becomes comparable in intensity with the lines present on the x-ray patterns at 4.2°K (outer lines). With further decrease in substrate temperature, the intensity of the two outer lines drops, and at 2.8°K only one in-



X-ray patterns of deuterium and hydrogen condensed on a copper capillary cooled to different temperatures.

tense middle line remains. The x-ray patterns of solid protium condensed at a temperature below 2.8°K become similar to the x-ray patterns of solid deuterium.

A striking fact is that the diffraction line of deuterium or protium has below 2.8°K a diatropic character in that all of its intensity is concentrated near the equatorial plane of the x-ray film. Above 2.8°K the central line on the x-ray pattern of protium spreads over ever increasing azimuth angles, and becomes practically isotropic at the temperature at which its intensity is approximately equal to the intensity of the outer lines.

The foregoing data on the temperature dependence of the diffraction pattern due to scattering of x-rays by solid samples of hydrogen isotopes do not contradict the assumed presence of a temperature-dependent texture in this sample.

In fact, these data can be explained in the following manner. At 4.2°K the preferred orientations in the deuterium and protium layers are such that the former produce on the x-ray patterns only one middle line (first type of texture) and the latter only two outer lines (second type of texture). This difference between textures in the deuterium and protium samples may be due to the fact that 4.2°K is a higher effective temperature for protium than for deuterium, for which it lies lower than the critical temperature corresponding to the transition from condensation with a preferred orientation of the second type to condensation with a texture of the first type; for protium it lies above the critical temperature.

Inasmuch as for deterium 4.2°K is lower than the critical temperature for the production of textures of two different types, an additional decrease in the substrate temperature no longer changes either the character of the texture or the form of the x-ray pattern. For protium, on the other hand, this critical temperature lies above 4.2°K, and a decrease in temperature leads to a change in the condensation conditions. A texture of the first type appears along with the texture of the second type. The relative number of grains with these orientations changes gradually with decreasing substrate temperature in favor of the orientation of the first type, and below 2.8°K the obtained layer of solid hydrogen has only this orientation.

The temperature dependence of the distribution of the intensity along the diffraction line can offer evidence that the degree of scatter of the texture decreases with decreasing substrate temperature. At a substrate temperature below 4°K the presence of both types of textures in the condensed layer, and the high degree of their scatter, leads to x-ray patterns which correspond to the scattering of x-rays by isotropic polycrystalline samples.

Another argument in favor ot the deduction that the temperature variation of the character of the x-ray patterns of the protium layers is connected with the difference in the textures of these layers at different temperatures is the fact that the diffraction pattern depends only on the condensation temperature. Subsequent heating to 4.2°K of specimens condensed at 1.3°K, or cooling to 1.3°K of specimens condensed at 4.2°K, no longer causes a change in the type of x-ray pattern.

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[1] Kogan, Lazarev, and Bulatova, JETP **37**, 678 (1959), Soviet Phys. JETP **10**, 483 (1960).

[2] Kogan, Bulatov, and Yakimenko, JETP **46**, 148 (1964), Soviet Phys. JETP **19**, 107 (1964).

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