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The Reflection and Diffraction of Molecular Beams at Lithium Fluoride Cleavage Surfaces

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In their study of the reflection and diffraction of molecular beams at crystal surfaces, Frisch and Stern[1] found certain anomalies which they suggested might be due to diffraction from a secondary structure such as was postulated by Zwicky.[2] It seemed desirable to investigate the matter further, as there were no conclusive proofs of the existence of such a structure. For this purpose many reflectivity curves of the following type were made. A beam of helium atoms or hydrogen molecules fell on a freshly cleaved lithium fluoride crystal at a glancing angle of 18 degrees and was reflected into a fixed slit which led to a hot wire manometer. The crystal was rotated about the axis in its face perpendicular to the plane containing the normal and the incident beam, and the intensity was plotted as a function of the angle.

It was found that the intensity patterns were not the simple triangles expected from theory, but contained varying numbers of maxima separated by angles of a degree or less. Typical examples are shown in Fig. 1. The same results were found with both hydrogen and helium. If they had been diffraction effects, the angular distances between consecutive maxima would have been different for the two gases. This is due to the fact that with the crystal, as with all gratings, the deviations of a diffracted beam depend upon the wave-lengths, and, for the small angles used here, are proportional to them. The ratio of the de Broglie wave-lengths of hydrogen and helium, and, therefore, the ratio of the distances between corresponding orders of diffraction, is $\sqrt{2}$ to 1. In every case these angular distances were exactly the same for both hydrogen and helium; a typical example is shown in Fig. 2. Here the angular separation for helium is one degree. That for hydrogen is certainly the same to within two or three minutes; it cannot possibly be $\sqrt{2}$ degrees or 1° 25′. Therefore, the effect cannot be explained as a diffraction effect. Thus there was found in the present work no evidence for the existence of a Zwicky structure. These results are not in agreement with those of Johnson[3] who found indications of diffraction from a secondary lattice when he was studying a beam of atomic hydrogen and detecting it by chemical means.

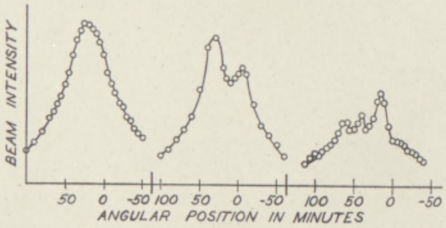

Fig. 1. Typical reflectivity curves.

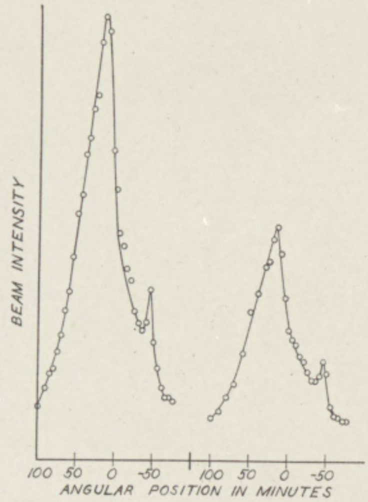

Fig. 2. Comparison of the reflectivity of hydrogen and helium.

A simple explanation of the shape of the curves is that the crystals, although considered single by ordinary criteria, are not ideal, but are made up of many crystallites of sizes up to a millimeter in diameter, tipped at small angles to each other. This would seem to verify the work of Renninger,[4] who found in his x-ray studies of the reflectivity of artificially grown rocksalt crystals that they were made up of microcrystals of the same size as those found in the molecular beam work, but with angles between them much smaller. This discrepancy might be due to the difference in the materials studied. The two effects are almost certainly related, but nothing more definite can be said until further investigations are made.

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