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SHORT NOTE**Differential Elastic Scattering of Helium Ions by Methane**

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(Received 24 August 1972)

Measurements of the rainbow phenomena in the differential elastic cross section have been performed on the system of He^+ ions and methane molecules using a crossed-beam apparatus¹⁾. Primary ions produced by electron bombardment were extracted by an exit lens to a rf-quadrupole mass filter. After the mass selection, He^+ ions were collimated by a transport lens and passed through an electrostatic deceleration lens system into the collision region²⁾, where the He^+ ion beam was crossed at a right angle by the molecular beam of methane from a multi-capillary nozzle³⁾. Typical widths of both ion and molecular beams were 1 mm (FWHM), respectively. Typical pressures in a main chamber were of the order of 10^{-9} Torr base pressure and about 10^{-7} Torr in the presence of both beams.

Elastically scattered He^+ ions which emerged from the collision region were distinguished from inelastically scattered He^+ ions by an energy analyzer of an electrostatic retardation potential type and were detected by a 16-stage electron

multiplier. The output signals from the electron multiplier were fed into a counting system.

Observed curves were a single undulation superimposed on a monotonically decreasing background, and any pronounced super-rainbow structures were not observed, which would be mainly due to the imperfect energy and angular resolutions of the apparatus. Plots of the relative differential cross section *versus* the center-of-mass scattering angle are shown for two different laboratory energies in Fig. 1. The differential cross sections in the figure are relative and do not reflect the variation of kinetic energies, and curves joining each point have no theoretical significance.

The results were interpreted by a three-parameter potential given by⁴⁾

$$V(r) = (\epsilon/2) \left\{ (1 + \gamma)(r_{\infty}/r)^{12} - 4\gamma(r_{\infty}/r)^6 - 3(1 - \gamma)(r_{\infty}/r)^4 \right\},$$

where ϵ is the depth of the potential well minimum, r_{∞} is the intermolecular

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Fig. 1. Relative differential elastic scattering cross sections *versus* the center-of-mass scattering angle for $\text{He}^+ + \text{CH}_4$ at the laboratory collision energies; $E = 22.4$ eV (●) and $E = 13.5$ eV (○). Estimated errors are denoted by the bars through the data points.

separation where the potential is minimum, and γ is a force parameter which lies in the range $0 \leq \gamma \leq 1$, which are adjustable parameters of the potential, respectively. The last term in the potential denotes the charge-induced dipole interaction and the relative strength of this term to others is determined by γ as it varies from zero to unity. The values of the rainbow angle at each collision energy were determined from the data and these were fitted to the calculation⁵⁾

$$-\theta_r(E/\epsilon) = 0.29 \gamma + 1.75,$$

where θ_r and E represent the rainbow angle in radians and the kinetic energy in the center-of-mass frame, respectively. The values show good agreement within the accuracy of 0.3 % with those calculated by Ioup and Thomas⁶⁾ provided that the reduced kinetic energy $K(=E/\epsilon)$ is not less than 5. From this relation the potential depth is given in term of γ as

$$\epsilon = -2.80 / (0.29 \gamma + 1.75) \text{ (eV)},$$

and -1.50 eV for $\gamma = 0.4$. The determination of r_* is also possible from the rainbow undulation. However, the value

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of r_m is rather sensitive to the curve shape and hence it depends on the potential anisotropy⁷⁾, so that the potential used would not be adequate and r_m from such relative cross section measurements alone is not particularly reliable. A detailed account of the calculations will be published shortly.

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