Cross Section for the Reaction $H^2+H^2\rightarrow H^1+H^3$ With a Gas Target

The absolute cross section for the reaction $H^2+H^2\rightarrow H^1+H^3$ has been determined for bombarding energies from 50 to 390 electron kilovolts and with a target of *deuterium gas* at 0.1 mm pressure. The magnetically analyzed beam of deuterons enters the target chamber through a 12 cm long canal comprising 5 defining holes of diameters 1 to 2 mm, traverses the target volume, then passes through an exit canal into a Faraday cup. No foils are used. Satisfactory vacuum conditions in the accelerating tube and Faraday cup are maintained by fast pumps.

Results of preliminary measurements are tabulated below:

Bombarding Energy, E	50	100	200	330	390 Kev
Total Cross Section, $\sigma\times10^{26}$	1.4	1.6	2.5	3.8	4.9 cm^2

Subject to the next paragraph, the probable error in each value is estimated at 6 to 8 percent due to all causes except contamination of the beam with light hydrogen. The extent of this contamination is not known, but the relative intensities of the mass 1, 2, 3, and 4 spots make it seem very unlikely that it exceeds 20 percent. The tabulated cross sections are low by the corresponding amount.

Recombination of the ions in the beam in passage through the target would result in a spuriously low beam measurement. The best experimental evidence on this point at present is that no change in beam current is observed when gas is admitted to the target chamber to raise the pressure from 0.005 mm to 0.1 mm. Since, however, about a minute is required for this operation and since it is difficult to maintain a steady, focused beam of the necessary intensity ($\sim1\mu$a) through the narrow entrance canal, this observation is insensitive to changes of 10 to 20 percent.

A direct check on the recombination is now being made by passing the beam, after it emerges from the exit canal, between the faces of a deflecting electromagnet, then onto a solid deuterium target. If there are neutral deuterium atoms in the emerging beam, the corresponding proton yield from bombardment of the solid target will persist when the magnet is on.

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The Normal Modes of Oscillation of the Long Chain Paraffin Hydrocarbons

E. J. Routh[1] describes a method of finding the normal modes of vibration of a finite chain of similar systems. The authors have applied this to the vibrations of the members of the methane series (C_nH_{2n+2}). The model assumed consisted of N carbon atoms lying in a plane with the tetrahedral angle between their bonds and the hydrogen atoms in planes through the carbon atoms at right angles to this plane, the angle between the C−H bonds was also assumed to be the tetrahedral angle. The Lagrangian was set up by considering only the nth CH_2 group and its interaction with the four neighboring CH_2 groups. The forces were assumed to be simple harmonic and along the lines joining the particles. The following interactions were considered: H_n-C_n, H_n-H_n', C_n-C_{n+1}, C_n-C_{n+2}, H_n-C_{n+1}, H_n-H_{n+2}, H_n-C_{n+2}, and $H_n-H'_{n+2}$ together with the analagous interactions of the other atoms. Here H_n and H_n' indicate the two hydrogens and C_n the carbon atoms of a single CH_2 group. The force constants K_1, K_3, K_4, K_6, K_8, K_9, K_{10}, K_{11}, respectively, are taken with the interactions above.

The elongations and Lagrangian were expressed in terms of X_n, Y_n, Z_n, x_n, y_n, z_n, x_n', y_n', z_n', the coordinates of the C, H, and H′, atoms so taken that a rotation through 180 degrees and a translation along the C−C bond leads to the coordinates of the adjacent CH_2 group. The equations of motion obtained from the Lagrangian are satisfied by solutions of the form $X_n=A\exp i(\omega t-\lambda n)$, $Y_n=B\exp i(\omega t-\lambda n)$, etc., where A, B, etc. are constant amplitudes, ω the angular velocity, and λ the phase angle between the vibration of successive CH_2 groups. There thus results a set of nine simultaneous linear equations in A, B, C, a, b, c, a', b', and c', which have solutions only if the ninth-order determinant of the coefficients vanishes. This ninth-order determinant can be diagonalized into one fifth- and one fourth-order determinant. These then form two equations in ω and λ whose roots in ω for a given λ give the nine fundamental frequencies of oscillation of the molecule.

Explicit solutions of these for ω in terms of λ, the dimensions and the force constants, cannot be obtained. However, roots may be obtained easily when $\lambda=0$ and $\lambda=\pi$ for in this case the fifth-order determinant further simplifies to a quadratic and a cubic and the fourth-order determinant to a cubic and a single root. For $\lambda=0$ there is one zero root and for $\lambda=\pi$ there are two corresponding to translations along the three coordinate axes.

In order to determine the dependence of the normal frequencies on the phase angle, λ, the authors have applied this work to the infra-red spectrum of undecane ($C_{11}H_{24}$) as measured in this laboratory with a NaCl prism spectrograph in the region from 1μ to 15μ. The potential energy constants K_1, K_3, K_4, K_8 were determined from four intense bands and it was assumed that K_{10} was equal to K_8 and that K_6, K_9, and K_{11} were negligible. Using the constants thus determined the normal frequencies for $\lambda=0$, 5, 45, 90, 135, 175, and 180 degrees were determined. It was found that the variation of the frequency with the phase was in most cases very slight and that accordingly the phase could be neglected. The nine fundamental frequencies, their overtones and simple combination bands were found to account for all of the observed bands within seven percent which is well within the accuracy of the constants and dimensions used.

A paper covering the development of the equations and the calculations will be presented later for publication.

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[1] E. J. Routh, *Advanced Rigid Dynamics* (Macmillan, 1930), p. 276.