determined in this experiment indicate that such large polarizations at large distances do occur.

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EXCITATION OF THE 2p STATE OF HYDROGEN BY ELECTRONS OF NEAR-THRESHOLD ENERGY*

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Recent experimental work in several atomic gasses[1-4] indicates that cross sections for excitation of optically allowed transitions by electron impact show a gradual rise from zero at threshold. For electric quadrupole transitions, the cross sections rise more sharply and reach a finite value at or very near threshold. In the case of atomic hydrogen, the near-degeneracy of the 2s and 2p states suggests that the 2s and 2p excitation functions might exhibit a superposition of these characteristics. Damburg and Gailitis[5] calculated the excitation cross sections of the 2s and 2p states of hydrogen in a 1s-2s-2p close-coupling approximation and found values near threshold which do not tend to zero. We have studied experimentally the threshold region of the cross section $Q_\perp$ for electron impact production of Lyman-α photons (1216 Å) from the 2p-1s transition in atomic hydrogen. We find that the cross section rises very steeply to a maximum, decreases to a minimum in about 0.3 eV, and then rises to a broad maximum.

The experiment was carried out in a differentially pumped high-vacuum crossed-beam apparatus. Hydrogen was thermally dissociated in a tungsten oven at 2500°K. The evolved H beam had a density of ~10^9 cm^{-3} at the interaction region. The ~1.5-μA electron beam was produced by a high-perveance electrostatic gun with axial symmetry. A Soa-type acceleration stage[6] was followed by a decelerating lens which focused the electrons into a field-free reaction space. Entrance and exit apertures assured that the electron beam trajectories passed through the 1-cm-wide atom beam. About 2% of the current passed into a hemispherical retarding analyzer,[6] which had a design resolution, $\Delta E/E$, of 0.25%. The electron energy distribution was measured at 10 eV by a modulated retarding potential technique.[7] The distribution, uncorrected for analyzer resolution, had a width at half-maximum of 0.35 eV and could be accurately represented by $dI/d\chi = 475 I\chi^2 e^{-9.83\chi}$, where I is the total electron current and χ is the energy in eV above the onset of the distribution.

Radiation from the interaction space was observed along an axis perpendicular to the crossed beams at a distance of 16 mm, using an ionization chamber filled with nitric oxide and having a 16-mm-diameter LiF window. The spectral response of such an ionization chamber extends over ~250 Å, but no atomic hydrogen line other than Lyman-α lies within this range. The threshold for excitation of H_2 to states which radiate within this band is 1.4 volts above the Lyman-α threshold. Quenching of the $2s$ state in the interaction volume by static electric or magnetic fields, or by collision with electrons,[8] was estimated and found to be negligible. All atoms pass out of view of the detector before impacting on any surface. Any background radiation is discriminated against by chopping the atom beam at 100 cps and using synchronous detection.

The observed energy dependence of the production of Lyman-α is shown in Fig. 1. The plateau near 11.6 eV is about one-third of the observed signal at 30 eV. Measurements taken

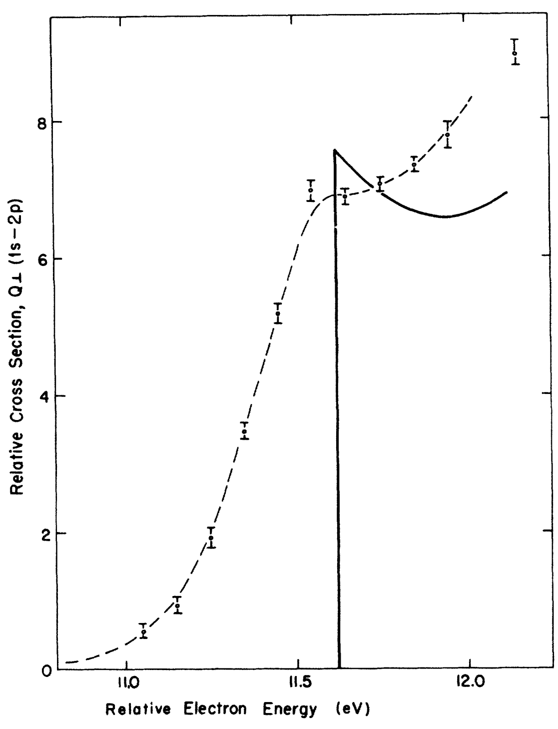

FIG. 1. The solid curve represents the atomic hydrogen excitation function, $Q_\perp(1s-2p)$, as unfolded from the experimental points using the electron energy distribution given in the text. The dashed curve shows the fit to the experimental data obtained by integrating the distribution function over $Q_\perp$. The energy scale relates to applied cathode voltages, uncorrected for contact potentials, and the ordinate is in arbitrary units.

at 0.1 eV intervals starting at 11.05 eV on the uncorrected energy scale of Fig. 1 yielded the following values: 0.56, 0.94, 1.92, 3.47, 5.17, 6.96, 6.87, 7.05, 7.34, and 7.77 in arbitrary units. Each error shown in Fig. 1 is the standard error of the mean of twelve measurements. Errors are typically ±0.10 to ±0.15 in the same units.

We integrated the energy distribution over various trial cross sections in attempting to fit the experimental results. A step function or monotonically increasing cross section does not result in a good fit. A close fit to the data is obtained by assuming the cross section to be finite at threshold and to have a quadratic dependence on energy immediately above threshold. The solid line in Fig. 1 shows a trial cross section of the form

$$Q = 9.50(E-11.62)^2 - 6.00(E-11.62) + 7.531,$$

where $(E-11.62)$ is the energy in eV above the assumed threshold. Integration of our electron distribution over this trial cross section yields the dashed curve in Fig. 1. Considering the simplicity of our trial cross section, the fit to the experimental points is quite good.

The theoretical results of Damburg and Gailitis indicate a wider and deeper minimum than the one we have obtained; a parabola fitted to their calculated cross section values does not yield a good fit to our experimental points. Earlier measurements, by Fite, Stebbings, and Brackman,[9] were interpreted as being consistent with a cross section rising from threshold with a square root dependence on the excess electron energy.

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BARYON-EXCHANGE MODEL IN ISOBAR PRODUCTION*

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Baryon exchange has been considered in low-energy pion-nucleon elastic scattering with considerable success.[1] The purpose of this note is to extend the idea to inelastic isobar production processes and to present some experimental evidence for the mechanism.

Consider the general reaction

$$M_i + B_i \to M_f + B_f,$$

where M_i, M_f, B_i, and B_f are initial meson, final meson, initial baryon, and final baryon, respectively. The baryon-exchange graph is shown in Fig. 1(a). The two incident particles, M_i and B_i, with four-momenta k_i and p_i, collide by exchanging a single virtual baryon B with four-momentum Δ. The final-state particles, M_f and B_f, emerge with four-momenta k_f and p_f. The rest masses of M_i, M_f, B_i, and B_f are w, w', W, and W', respectively. In the metric used,

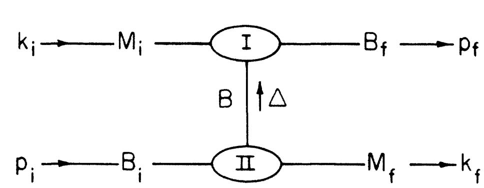
$$k_i^2 = -w^2.$$

The squared four-momentum of the exchanged baryon is given by

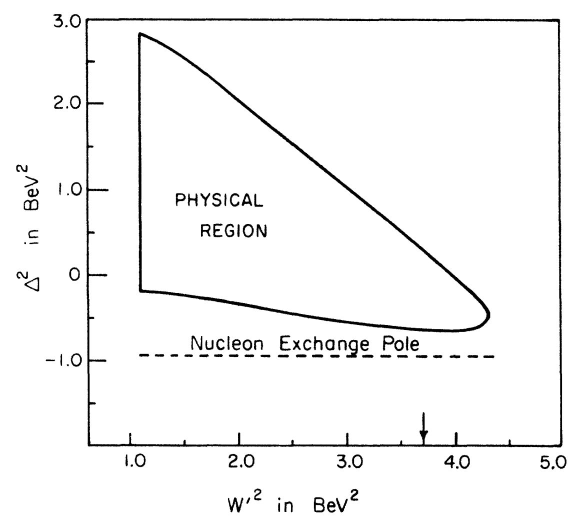
$$\Delta^2 = (p_f - k_i)^2 = (p_i - k_f)^2.$$

Whether Δ^2 is spacelike (positive) or timelike (negative) depends on the relative masses of the particles involved.[2] If baryon exchange is to become important it should appear when Δ^2 is a minimum (as timelike as possible), so that the physical region approaches the pole $\Delta^2 = -m_B^2$, where m_B is the rest mass of the exchanged baryon.

Consider the case where $W' > w$, $W > w'$, and B_f is an isobar which decays strongly into two particles. A Chew-Low diagram[3] of the squared effective mass of the decay paticles, W'^2, versus Δ^2 will then be of the form shown in Fig. 1(b). Note that in this case Δ^2 can be timelike. The



(a)



(b)

FIG. 1. (a) Baryon exchange diagram for the reaction $M_i + B_i \to M_f + B_f$. k_i, p_i, k_f, and p_f are the four-momenta of initial meson M_i, initial baryon B_i, final meson M_f, and final baryon B_f, respectively. B is the intermediate baryon with four-momentum Δ. (b) Chew-Low diagram for the reaction $\pi + p \to \pi + \pi + N$ for 2.16-BeV/c incident pions. W' is the effective mass of the final-state nucleon and one of the final pions. Δ is the four-momentum transfer between the initial nucleon and the remaining final pion. The arrow indicates the position of the $\Delta(1920)$ isobar.