ELECTRON-IMPACT EXCITATION OF THE 6^2P STATES IN CESIUM*

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The ratio of the differential cross sections at zero-angle scattering for the excitation of the $6^2P_{1/2}$ and $6^2P_{3/2}$ states in Cs has been measured for incident-electron energies between 3 and 68 eV. At 68-eV incident-electron energy the ratio is found to be 1.85, as predicted from degeneracy, but decreases significantly below 20-eV incident-electron energy.

The electron excitation of the states $6^2P_{1/2}$ and $6^2P_{3/2}$ in cesium vapor has been studied both experimentally[1,2] and theoretically[3,4] by a number of workers. All experimental observations to our knowledge have been of total cross sections for the excitation of these states together. However, it has been assumed[1] that the ratio of the cross sections for $6^2P_{1/2}$ and $6^2P_{3/2}$ is essentially given by the ratio of the degeneracies, and otherwise only depends on the difference in thresholds for the excitation of the two states. Theoretically Vainstein, Opykhtin, and Presnyakov[4] have given the total cross sections for the excitation of the two states separately using (a) the Born approximation, and (b) a model which emphasizes the repulsion of the atomic electrons by the incident electron and makes an allowance for electron exchange. But for a consideration of the two individual states $6^2P_{1/2}$ and $6^2P_{3/2}$, this work is limited to the extent that only degeneracy and the difference in thresholds are taken into account. We have used a high-resolution crossed-beam electron energy-loss spectrometer[5] to measure the ratio of the differential cross sections for electron excitation of the states $6^2P_{1/2}$ and $6^2P_{3/2}$ in cesium from the ground state $6^2S_{1/2}$ for forward scattering as a function of incident-electron energy over the range 3-68 eV; the threshold for excitation of these two states is approximately 1.4 eV. It is hoped that the results of these investigations will stimulate further theoretical consideration of this problem.

Figure 1 shows part of the energy-loss spectrum of cesium in the region of the 6^2P doublet; the resolution of the spectrometer was better than 35 mV. The results of our measurements are shown in Fig. 2. In our data the incident-electron kinetic energy has not been corrected for errors due to contact-potential differences; such errors can be expected to add between 0.5 and 1 eV to the observed values. The zero scattering angle has been defined to better than 0.5 deg. Such high angular resolution is particularly important at high values of the incident-electron

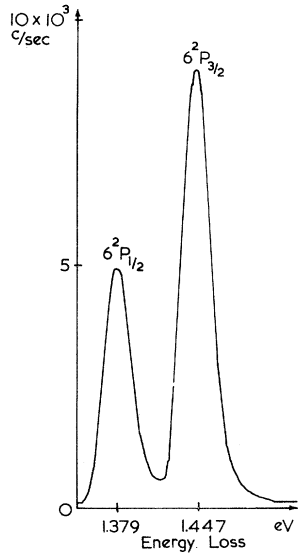

FIG. 1. Electron energy-loss spectrum of cesium in the region of the transitions $6^2S_{1/2} \rightarrow 6^2P_{1/2}$ and $6^2S_{1/2} \rightarrow 6^2P_{3/2}$, at 50-eV incident-electron kinetic energy.

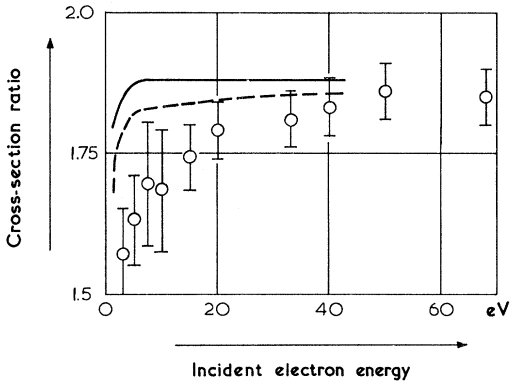

FIG. 2. Comparison of cross-section ratios, $\sigma(6^2P_{3/2})/\sigma(6^2P_{1/2})$, for excitation of 6^2P states from the ground state 6^2S in cesium. Open circles: this research, differential cross sections (energy scale uncorrected, see text). Broken line: total cross-section ratio, Born approximation. Solid line: total cross-section ratio derived from theoretical data of Vainstein, Opykhtin, and Presnyakov.[4]

kinetic energy, where the differential cross section for inelastic scattering is markedly dependent on the scattering angle. Also shown in Fig. 2 are ratios for the total cross section derived from the work of Vainstein, Opykhtin, and Presnyakov.[4] These theoretical values have been used for comparison with our differential cross-section ratios since no closer theoretical data are available. Although a comparison of total and differential cross sections is not completely satisfactory, we feel that it is justified for cross-section ratios for dipole transitions.

As can be expected, the theoretical curves agree well with our data at high incident-electron energies. Furthermore, at high incident energies we can use the Born approximation to obtain the differential cross section from the optical line-strength ratio. The latter has been determined experimentally and found to be 2.1 ± 0.2.[6] From this value we derive a differential cross-section ratio of 1.9 ± 0.2, which is in good agreement with our measurements at high energies.

At low incident-electron kinetic energies the Born approximation cannot be expected to agree with our differential cross-section ratios. However, calculations based on the Vainstein model[4] are also constant over the range of our measurements. Only when the excess energy of the scattered electrons is comparable with the difference in energy of the thresholds of the two states do the Born approximation and the Vainstein model[4] predict a decrease in the cross-section ratio. It should be remembered that the lowest energy of the electrons after scattering in our experiment was 1.5 eV, and probably higher (see above for correction), and that this is approximately 20 times the difference in threshold energy for the $6^2P_{1/2}$ and $6^2P_{3/2}$ states. It seems possible that some improvement could be made in the theoretical calculations by the inclusion of spin-dependent forces in the Schrödinger equation.

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ROLE OF DISPERSION IN COLLISION-INDUCED ABSORPTION

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It is shown that theoretical calculations which use the exponential model $\vec{\mu} = \mu_0(\vec{r}/r) \times \exp(-r/\rho)$ for the variation of the dipole moment $\vec{\mu}$ with internuclear separation $\vec{r}$ can be forced into agreement with experiment only if one uses dipole parameters μ_0, ρ which are in serious disagreement with values computed by the molecular Hartree-Fock approximation. On the basis of a Drude model calculation, it is concluded that the exponential model is an inadequate representation of the true physical situation because of its neglect of electron correlation effects.

The elegant experiment by Bosomworth and Gush[1] has aroused considerable interest on the part of theoreticians, and several papers have appeared recently[2-9] in which theoretical calculations of the spectral line shape for collision-induced absorption in rare-gas mixtures or related systems have been made. In the first four of these papers (Refs. 2-5) a heuristic model was employed for the variation of the collision-induced dipole moment of a heteropolar rare-gas diatom with internuclear separation, which yields good agreement with experiment when certain parameters are suitably adjusted. We shall not discuss these calculations further here. In the second four papers (Refs. 6-9), the dipole moment was assumed to vary in what apparently is a physically realistic way:

$$\vec{\mu} = \mu_0(\vec{r}/r) \exp(-r/\rho). \quad (1)$$