RESONANCES IN THE INELASTIC CROSS SECTION OF HELIUM*

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The paper presents experimental evidence for structure in the inelastic cross section in helium which is interpreted in terms of compound states above the lowest electronically excited state. A study of the inelastically scattered electrons at an angle of 72° shows that structure in the $2\,^3S$ cross section exists for electron energies around 21 eV and 22.4 eV.

Baranger and Gerjuoy[1] have suggested that the shape of the $2\,^3S$ excitation function is consistent with the existence of a compound state in the vicinity of the threshold of the $2\,^3S$ state. The existence of such compound states may be detected either in elastic or in inelastic scattering, or possibly in both channels. A pronounced resonance, resulting from a compound state, has been previously found[2] at an electron energy of 19.30 ± 0.05 eV in the elastic scattering channel. This resonance has been confirmed by other investigators[3,4] and can be considered to be well documented. The classification of the state[4] is $1s(2s)^2$. This paper reports the results of a search for similar resonances in the inelastic excitation of helium.

The double electrostatic analyzer described previously[2] has been used for this study. The first electrostatic analyzer forms an electron beam with a half-width about 0.06 eV. The electrons are accelerated into the collision chamber where they are crossed with an atomic beam of helium. Those electrons having lost energy in exciting electronic states of helium and having been scattered into the acceptance angle of the second analyzer are transmitted to the electron multiplier and measured at the output of the multiplier. The solid curve of Fig. 1 shows the current received as a function of electron energy for electrons having lost 19.8 eV of energy; thus, this curve represents the differential excitation cross section (for electron scattering at 72°) to the $2\,^3S$ state of helium. The top, dashed, curve shows the results of a previous experiment by Schulz and Fox,[5] in which the total metastable production as a function of electron energy has been measured. The low-energy portion of this curve (up to 22 eV) has been published previously and the extension to higher energies presents previously unpublished data. The curve, obtained by measuring the electrons ejected from

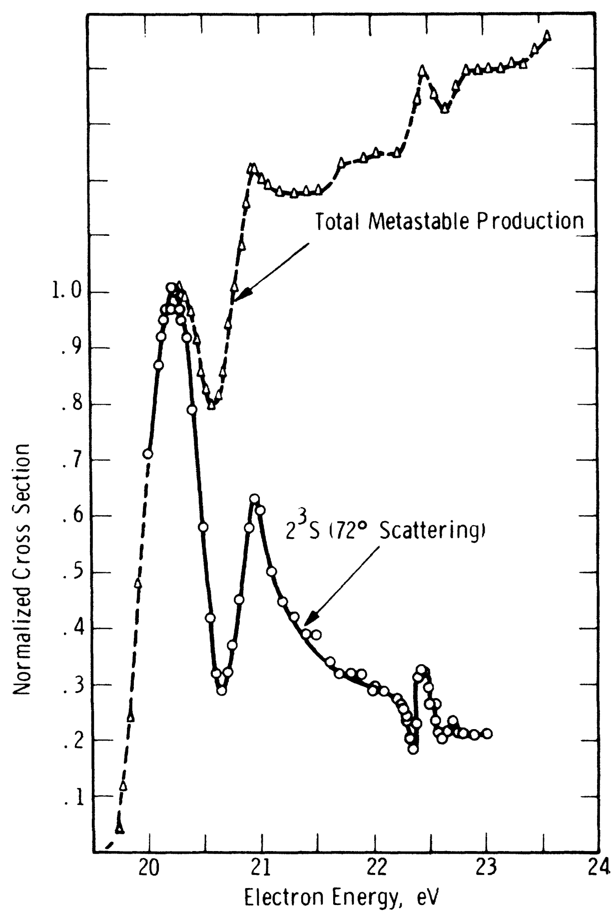

FIG. 1. Energy dependence of inelastic cross-sections in helium. The solid line represents the cross-section vs electron energy for electron scattered at 72° and having excited the $2\,^3S$ state. The dashed line is the total metastable production, obtained by Schulz and Fox, using the retarding potential difference method.

a metal surface, represents the sum of the excitation functions to all metastable states (including cascading to these states). This curve has been interpreted in the past as representing the excitation of the $2\,^3S$ state up to 20.6 eV, the rise commencing at 20.6 eV being due to the onset of the $2\,^1S$ state. The small hump at 22.4 eV could not be assigned to any particular excitation channel. It should be noted that this hump is completely consistent with the data of Dorrestein,[6] who observed a rise in this energy range. Unfortunately, his published curve terminates just above the rise. The energy scale of the 2^3S curve of Fig. 1 is calibrated from the helium resonance at 19.30 eV. The position of the structure agrees well with that of the total metastable production curve, which is plotted on an independently calibrated energy scale.

The present curve for the 2^3S state alone (bottom curve of Fig. 1) exhibits a rise starting at 20.6 eV. This structure may be indicative of a second compound state in helium. All, or at least a portion, of the rise of the total metastable excitation function at 20.6 eV may result from the rise of the 2^3S channel. It must be realized that, without knowing the angular distribution of electrons after excitation of the 2^3S state, it is not possible to estimate the contribution which the rise commencing at 20.6 eV makes to the total excitation function.

If one arbitrarily assumes that the scattering of electrons having excited the 2^3S state is isotropic, it would follow that the shape of the solid curve of Fig. 1 is representative of the 2^3S excitation cross section. Subtracting the 2^3S curve from the total metastable production curve would lead to the result that the 2^1S excitation function rises very steeply.[7]

The structure around 22.4 eV is shown in more detail in Fig. 2. We interpret this structure as evidence for a third compound state lying approximately 0.3 eV below the lowest $n=3$ excited state (probably of the $1s3s$ configuration with an extra electron). The complex shape of this resonance is reproducible, but probably not completely resolved with the present energy spread. The complexity of the shape would indicate the existence of two or more compound states within a few tenths of an eV. Preliminary data show that the structure around 22.4 eV is reflected also in the 2^3P and 2^1P channels. No structure in this energy range has been detected either in the 2^1S or the elastic cross section.

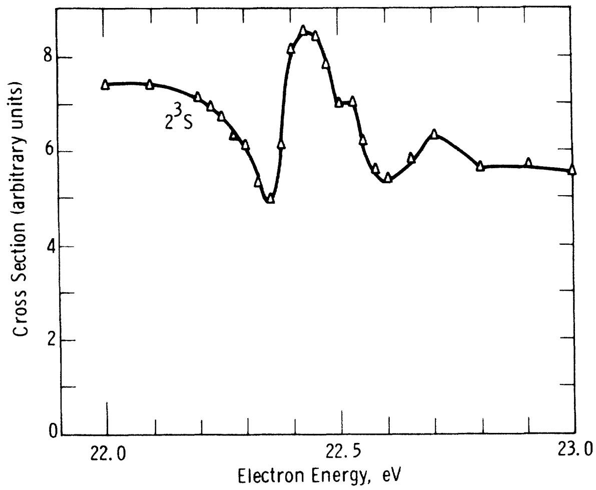

FIG. 2. Details of the resonance observed around 22.4 eV in the 2^3S channel obtained from electron scattering at 72°.

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[7]It may be interesting to note that such a sharp onset has been predicted theoretically for atomic hydrogen by R. Damburg and M. Gailitis, Proc. Phys. Soc. (London) 82, 1068 (1963), and observed experimentally by S. J. Smith, D. W. O. Heddle, and G. E. Chamberlain, Bull. Am. Phys. Soc. 9, 535 (1964).