NEGATIVE IONS IN ELECTRON IMPACT EXCITATION OF He NEAR 60 eV

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Received 12 August 1974

An experimentally verifiable effect on the excitation cross section in helium due to the broad $(2s2p^2)\ {}^2S^e$ He^- state predicted by Fano and Cooper in 1965, but hitherto unidentified, and other He^- states, are predicted.

The narrow $(2s^22p)^2P^o$ and $(2s2p^2)^2D^e$ He^- states in the 57 to 60 eV region have been frequently discussed [1–7], but the broad $(2s2p^2)^2S^e$ He^- state [1] was tentatively considered only by Grissom et al. [2] as being perhaps responsible for one of the structures seen in their spectra. Using a previously described multiconfiguration close coupling model [7], we have located this state at 59.4 eV with a width of approximately 300 meV as well as other He^- states associated with higher ($n = 3$) doubly excited states of He. These results may guide interpretation of structures observed, but not identified, in trapped electron spectra [2], in optical excitation functions [3] and possibly in the electron impact He ionization spectra [4]. The positions and suggested dominant configurations of the new negative ion states are summarized in table 1.

For the $n = 2$, $^2S^e$ calculations we include the $(1s^2)^1S$, $(1s2s)^3S$, $(2s^2)^1S$ and $(2s2p)^{1,3}P$ states of He in the expansion of the total wave function. This $^2S^e$ state decays mainly to the $(2s2p)^3P$ and $(1s2s)^3S$ but, in agreement with recent experiments [6], no effect is seen in the ground state channel. The effect of the resonance on the $(2s2p)^3P$ excitation cross section is shown in fig. 1. The essential properties of this resonant state do not change when the $(1s2s)^1S$ state is added to the eigenfunction expansion, nor when either the $(2s^2)^1S$ or the $(2s2p)^1P$ are left out, but it narrows drastically to a few meV and shifts to a higher (~ 60 eV) energy when the $(2s2p)^3P$ state is omitted. The apparent non-negligible decay to the $(1s2s)^3S$ channel led us to examine the 2^3S differential cross section in the range 58.4 to 60.1 eV. The shape and value variations such as those shown in fig. 2 are especially evident in the angular range of 30–110°. Although channels not included in the model permit in reality additional decay paths, these changes might be detectable with current techniques.

As shown in table 1, structures observed in the 60–64 eV range by Grissom et al. but not assigned by them to doubly excited states of He, and features that can be discerned in other reported spectra [3, 4], can be correlated with negative ions formed by attachment to such doubly excited states as those designated by $23sp^+$ [8]. These negative ions can also be studied with the close coupling model in analogy with those bound to the $2s^2$ and the 2s2p configurations. The six new states given in table 1 result from an expansion including the $(1s^2)^1S$, $(1s3p)^3P$ and $(2s3p)^2P$ states, and the two series obtained correspond to the incident electron being captured into the $n = 2$ or the $n = 3$ shell, with the former lying lower. The widths of these states are of the order of a few meV but, just

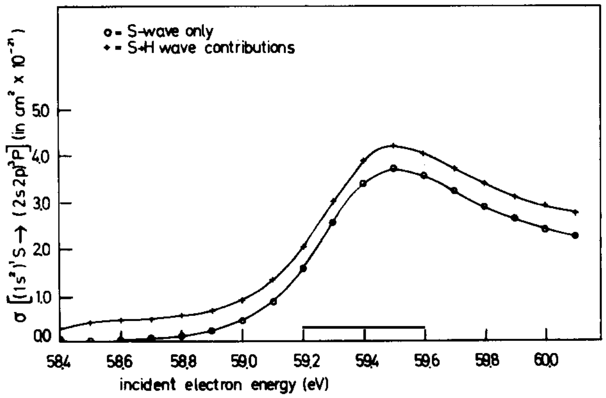

Fig. 1. Excitation cross section for $(2s2p)^3P$.

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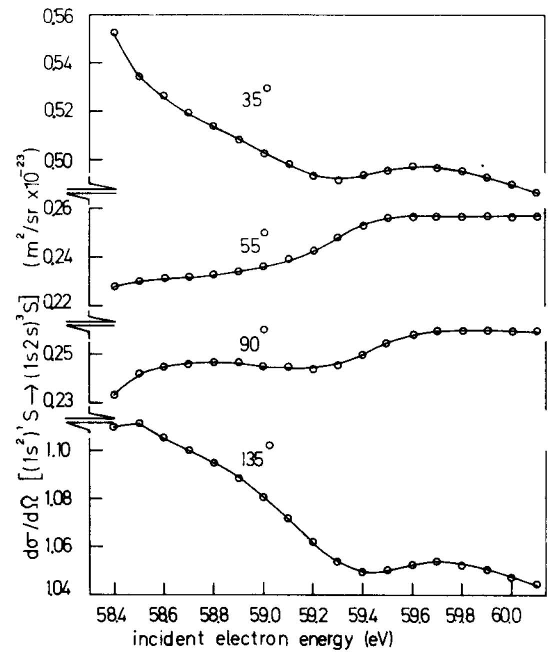

Fig. 2. Differential cross section of $(1s2s)^3S$. Note the different scales.

as for the $n = 2$ $^2S^e$ state, more realistic estimates of the (presumably) larger widths would result from calculations with He** levels below the He⁻ states. This is simply our model analogue of broadening of structures due to negative ion formation by interaction with lower doubly excited configurations which sometimes precludes their detection [1].

Only one of the new states, that at 62.4 eV, is seen in *both* the trapped electron and excitation function spectra which implies it may be strong enough to be also seen in electron transmission experiments. We suggest it is the ^2D state we find at 62.95 eV, bound to the $(2s3p)^1P$ state, as could be verified by angular distribution measurements. The feature at 58.79 eV in the spectra of Grissom et al. appears to be a ^2P state here located at 59.14 eV. It could alternatively be due to the $(2p^3)^2P$ state which is strongly depressed by configuration mixing. A search for resonances bound to the $2p^2$ configuration is now in progress.

Table 1
Calculated positions of He⁻ resonances and corresponding features in the measurements of (H) Heideman et al. [3], and (G) Grissom et al. [2].

Theory		Experiment	
Probable "dominant" configuration	Position (eV)	H	G
$(2s2p^2)^2S$	59.4	59.7 – 59.9(?)	59.42
$(2s^23p)^2P$	59.14		58.79(?)
$(2s2p3p)^2D$	60.17		60.41
$(2s2p3p)^2S$	60.35		
$(2s3p^2)^2D$	62.95	62.4(?)	61.93
$(2s3p^2)^2S$	63.32		62.43
$(2s3s3p)^2P$	63.45		

The authors thank Dr. P.J. Hicks for communicating his results prior to publication and S.O. acknowledges the hospitality of Prof. J.A. Smit and members of the Physics Department at the State University of Utrecht. This work is part of the research program of the Foundation for Fundamental Research on Matter (F.O.M.) made possible by financial support from the Netherlands Organization for Pure Research (Z.W.O.).

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