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TECHNICAL REPORT 21

RESONANCES IN THE ELASTIC SCATTERING OF ELECTRONS
ON ATOMS AND MOLECULES

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G. J. SCHULZ

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Contract Number: NONR 2584(00)

Project Code: 2720

Principal Investigators: A. V. Phelps
G. J. Schulz

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Physics Department
Westinghouse Research Laboratories
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RESONANCES IN THE ELASTIC SCATTERING OF ELECTRONS ON ATOMS AND MOLECULES*

G. J. Schulz
Westinghouse Research Laboratories
Pittsburgh, Pennsylvania, U.S.A.

~~This paper presents~~ ^{Experimental evidence} ^{is presented} for the existence of compound states in simple atomic and molecular systems. The experimental evidence for these compound states comes from the observation of the elastic and inelastic cross section by electron impact. Once formed, the compound state can decay into any state of the atoms which lies below it; namely, back to the ground state of the atom or molecule (elastic scattering), to an electronically excited state of the atom or molecule, to vibrational states of the molecule, or to a negative ion plus a neutral fragment. The compound states discussed in this paper occur below the first electronically excited state of the atom or molecule; they have been observed in helium and neon atoms, and in the molecules nitrogen, carbon monoxide, and nitrous oxide. ↗

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Experiment

A beam of essentially monoenergetic electrons (half width about 0.06 eV) is crossed by an atomic beam; the electrons scattered at an arbitrarily chosen angle (72 degrees) are analyzed and collected. Electrostatic analyzers¹ are used for creating the monoenergetic electron beam and for analysis of the scattered electrons.

Results

Figure 1 shows a plot of the elastic cross section in helium vs electron energy in the region around 19.3 eV. The sharp resonance at 19.3 eV represents a decrease of 14% in the elastic cross section. The half-width of the resonance, of about 0.06 eV, is instrumental and represents a lower limit for the lifetime of the state involved, namely, 10^{-14} sec. If the elastic cross section were to go to zero at 19.3 eV, the width of the resonance would be reduced by about a factor of seven, corresponding to an upper limit of the lifetime about 7×10^{-14} sec. The resonance has been interpreted¹ as a destructive interference between potential scattering and resonance scattering resulting from the formation of the compound state.

Figure 2 shows the resonance in the elastic cross section of neon, occurring again about 0.5 eV below the first electronic level of the atom. The dip in neon is only about 3%. No dip has been found in argon.

Figure 3 shows the structure in the elastic cross section of molecular nitrogen. This structure is indicative of the compound state of N_2 around 2.3 eV, previously postulated from experimental evidence.² In the

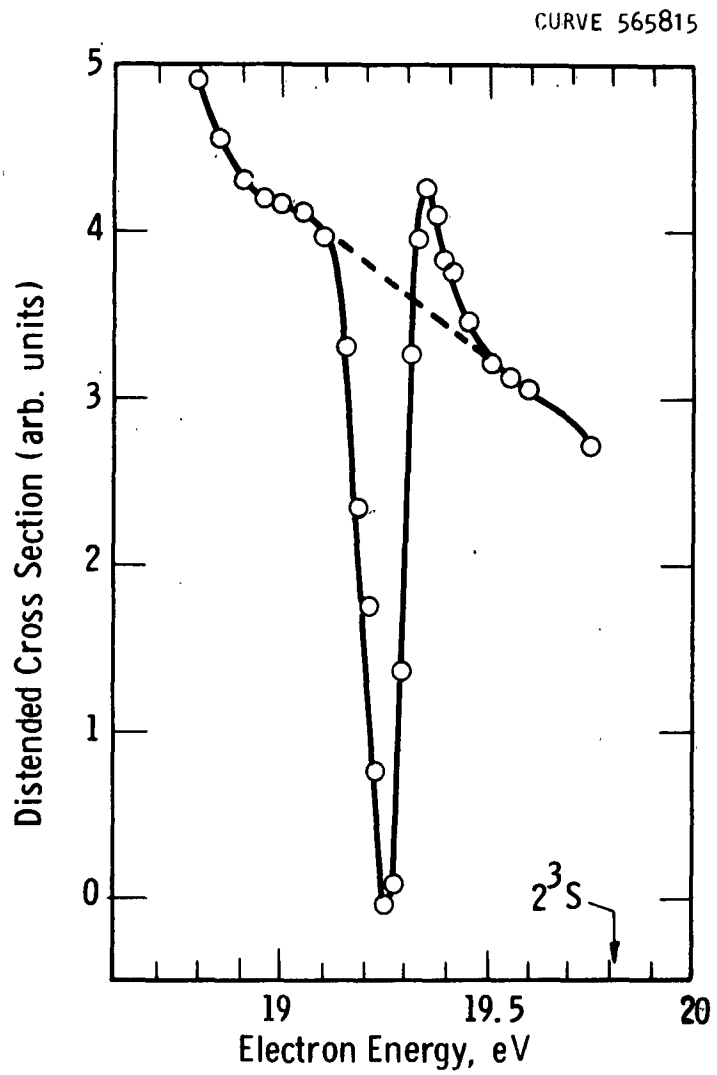
case of nitrogen, new channels of decay exist for the compound state, namely the formation of a vibrationally excited molecule plus a free electron. This effect has been observed.² In fact, the structure of the elastic cross section closely resembles the structure of the vibrational cross section to various vibrational states.

There is a possibility that many compound states are not observable in the present experiment; if the lifetime of the compound state is long, (e.g., longer than 10^{-12} sec for equal amplitudes of potential and resonance scattering) then the resonance would be so sharp that with the limited energy resolution available, one would not be able to observe such states. The existence of compound states must be taken into account in calculations of the excitation cross section near threshold,³ in some double excitation processes,⁴ in some autoionization events,⁵ in vibrational excitation,² and in some cases of negative ion formation.⁶ The existence of the compound state may be closely associated with metastable negative ions of the rare gases, such as He^- . The resonance in the elastic cross section of neon may be suggestive of the existence of a metastable negative ion Ne^- ; however, this ion has yet to be observed.

The author is indebted to A. V. Phelps for frequent stimulating discussions.

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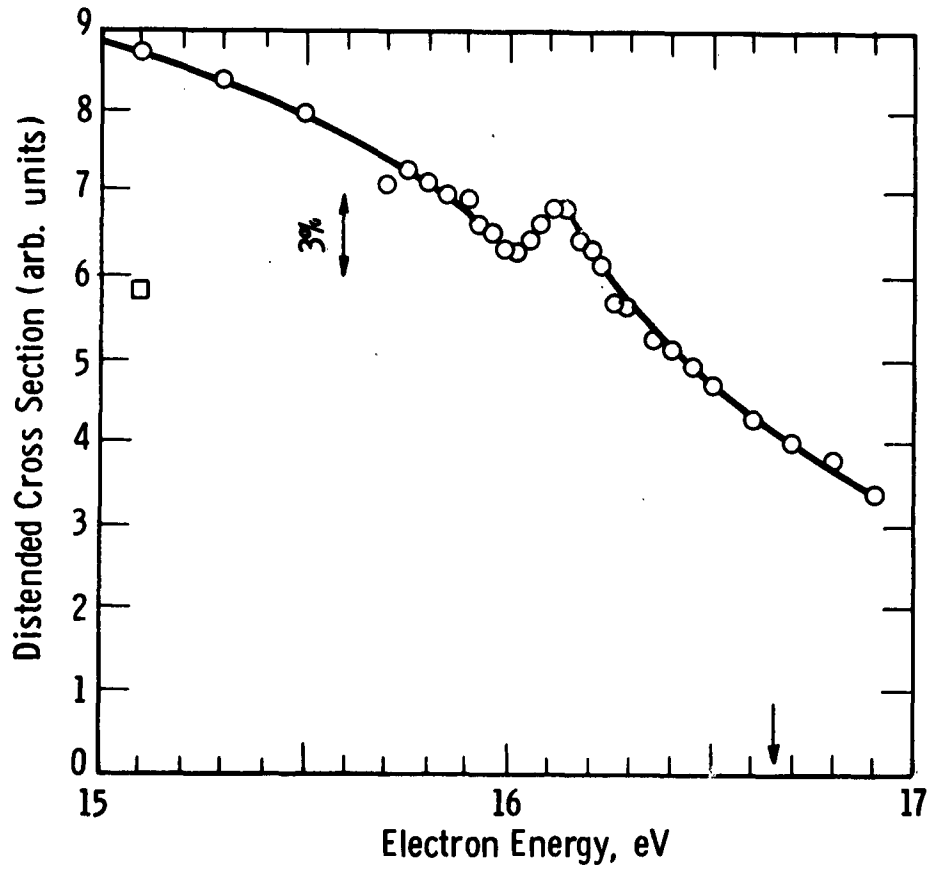
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Resonance in the elastic scattering of electrons
in helium

Figure 1

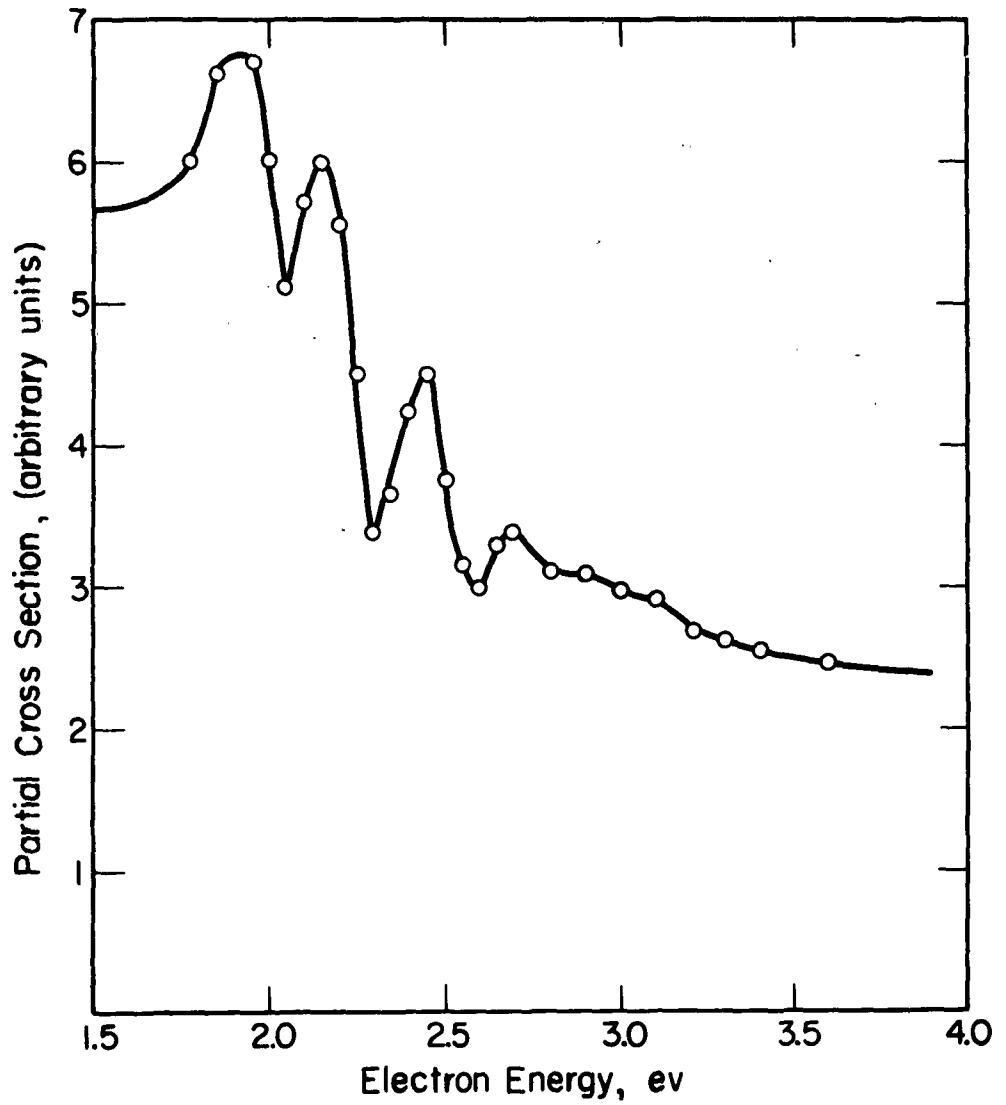
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Resonance in the elastic scattering of electrons in neon

Figure 2

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Elastic scattering of electrons in N₂ at 72 degrees.

Figure 3