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THE CONSISTENT DATA SET OF ANGULAR AND ENERGY DEPENDENT DCS FOR ELASTIC ELECTRON-ARGON SCATTERING IN THE VICINITY OF CRITICAL POINTS

A. R. MILOSAVLJEVIĆ, D. ŠEVIĆ, D. M. FILIPOVIĆ AND B. P. MARINKOVIĆ*

Institute of Physics, P O Box 57, 11001 Belgrade, Serbia and Montenegro
**Faculty of Physics, University of Belgrade, P O Box 368, 11001 Belgrade, Serbia and Montenegro*

ABSTRACT

The behaviour of differential cross section (DCS) for elastic electron-argon scattering was experimentally investigated in the vicinity of critical points. Angle dependent relative DCSs were measured in the angular range between 40^o and 130^o and energy range between 20 eV and 150 eV, in small angular and energy steps around critical points. Energy dependent DCSs were measured separately in the energy range between 90 eV and 150 eV and angular range between 70^o and 120^o in 10^o steps. The positions of deep minima in both angle and energy dependent DCSs were compared to the available previous results. It was shown, however, that there is a strong coupling between energy and angle dependence of DCSs in the vicinity of critical points and even slight difference of the fixed scattering angle could affect significantly the energy dependent DCS.

Keywords: argon, elastic scattering, critical points

1. Introduction

A large amount of data both experimental and theoretical, relevant for understanding elastic electron-argon scattering, has been obtained up to present. Usually, calculated and measured results were compared by presenting angle dependent differential cross sections (DCSs) at fixed incident electron energies. Also, an additional test was plotting the positions of DCS minima as a function of the incident energy. However, the critical minima in elastic electron scattering appeared to be the most sensitive test of the validity of both theoretical approaches and experimental procedures. These minima are defined by the points where DCS attains it smallest value as a function of *both* incident electron energy and scattering angle. In particular, for elastic electron-argon scattering, quite a few results focused on the determination of critical minima have been published [1]- [8]. Nevertheless, the only detailed experimental investigation of DCSs in the vicinity of critical points has been published by Panajotović *et al* [5], which, however, did not cover the high-energy critical minimum. Also, only the angle dependent DCSs were measured. In general, most of the previous experimental DCSs for elastic electron-argon scattering have been obtained as a function of scattering angle at well separated incident electron energies. There are very few reported results (beside the resonance measuring at small energies) that have been measured as a function of incident energies [9], [10], which also have not been focused on the critical minima. Finally, according to our knowledge, there are no published consistent data set for elastic electron-atom scattering that would be obtained by both energy and angular dependent measurements, and would present both energy and angular dependence of DCS in the vicinity of a critical point. A more detailed discussion regarding the completing of electron-atom scattering picture for rare gases could be find elsewhere [11].

In this paper, we present detailed measurements of DCSs for elastic electron-argon scattering in the vicinity of two critical minima. For the lower-energy minimum, only the angle dependent DCSs have been measured and normalized with respect to the energy dependent DCS at 100^o of Cvejanović and Crowe [10]. For the higher-energy minimum, both angle-dependent and energy dependent DCSs have been measured and absolute

calibration of the obtained data set has been performed according to the one single point. The main purpose of this work is investigation of both angular and energy dependence of DCS for elastic electron-argon scattering in the vicinity of critical minima.

2. Experiment

A concise description of the experimental apparatus with a schematic drawing has been given previously [12]. Also, the experimental procedures and the details of the experimental set-up used in the present measurements have been described recently [13]. In short, we used an electron spectrometer with an electron gun (with a hair-pain thermo-electron source), electron (ion) analyser and channel electron multiplier as a detector. The analysing system is consisted of simple four-element electron lens and double cylindrical mirror analyser (DCMA). The double μ-metal shield reduces the Earth and local magnetic fields to less than $2x10^{-7}$ T. During the measurements, all the parameters were kept in the range where the contribution of double electron scattering was negligible. Also, for the used angular range and experimental set-up, the influence of the effective path length to the obtained angular distributions was assumed to be negligible.

In the case of energy dependent DCS measurements, a special consideration of the most important energy dependent factors was needed. In order to obtain constant incident beam current in a broader energy domain, during the measurements the potential of the last (focusing) electrode of the electron gun was tuned for the applied incident energy. The beam current was monitored by a Faraday cup and also by using analyser system as a Faraday cup. Similarly, for the analysed electron energies, the transmission function of the four-electrode electron lens preceding the analyser was maintained constant by an appropriate choice of lens potentials, which were tuned for the applied incident energies as well. Moreover, the detailed investigation of the analyser lens transmission function has been made by using of electron trace simulations [14]. It was found to be constant for the used range of electron energies. The detection efficiency was kept constant by keeping the potential difference between the analyser cylinders constant, i.e. keeping the analyser transmission energy constant during the measurement.

3. Results

Low energies

We have measured angular distributions of electrons elastically scattered by argon in the angular range of 40°-110° in increments of 5° (2° or 1° around the minima) and at fixed incident electron energies from 30 eV to 60 eV, in increments of 2 eV. The obtained relative DCSs were normalized with respect to the energy dependent DCS at 100° that was obtained by Cvejanović and Crowe [10] as a continuous function of energy. In figure 1, present absolute angular dependent DCSs are presented, as well as previous experimental results of Panajotović *et al* [5] (figure 1b). These two data sets appeared to be in a very good accord. In figure 2a, the same results are presented, but as a function of incident energy at several fixed scattering angles close to the critical minimum. It could be seen that energy dependent DCSs are very sensitive to the scattering angle and even slight shift of it causes a significant change of energy dependent DCS minimum positions. In figure 2b, the present energy dependent DCS at 70° is compared to the available previous results. The DCS minimum is well determined by both present measurement and previous one of Cvejanović and Crowe [10]. Also, it is roughly determined by previous experimental results, which have been obtained by angle dependent measurements [15], [16], [17]. The recent calculated results of Sienkiewicz *et al* [7] agree well with the experiment, regarding minimum position. The theoretical DCS of Fon *et al* [18] appeared to be in a good accord as well, although the latter have been published with rather large energy steps so the exact position of minimum can not be determined. In figure 3, the present angle dependent DCSs at 40 eV and 50 eV are compared to the previous results. At both energies, a very good agreement in minimum position is achieved by all experiments, while the theoretical DCS at 40 eV of Fon *et al* [18] is slightly shifted towards higher angles.

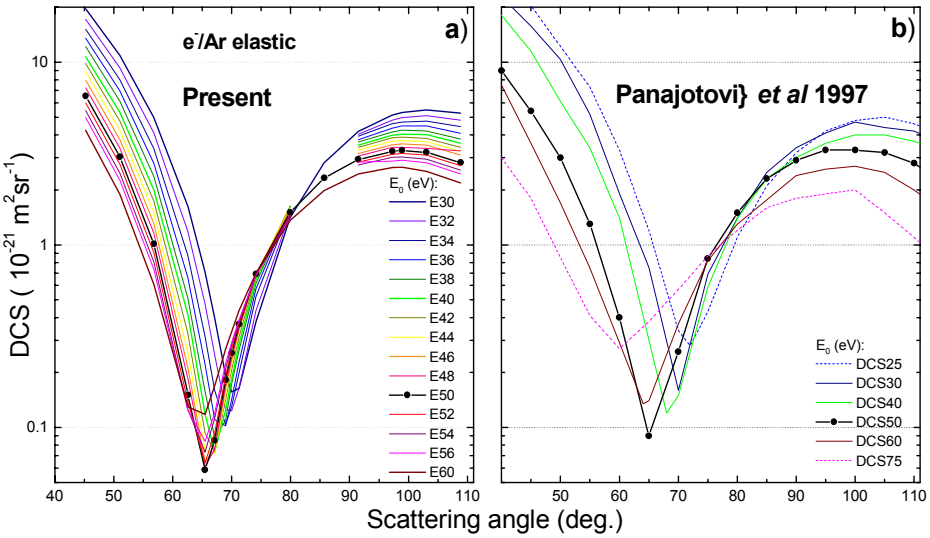

Fig. 1. *The angle dependent DCSs for elastic electron-argon scattering in the vicinity of the low-energy critical minimum: a) present results; b) Panajotović et al 1997 [5]. The presented curves are obtained by connecting the experimental points with straight lines.*

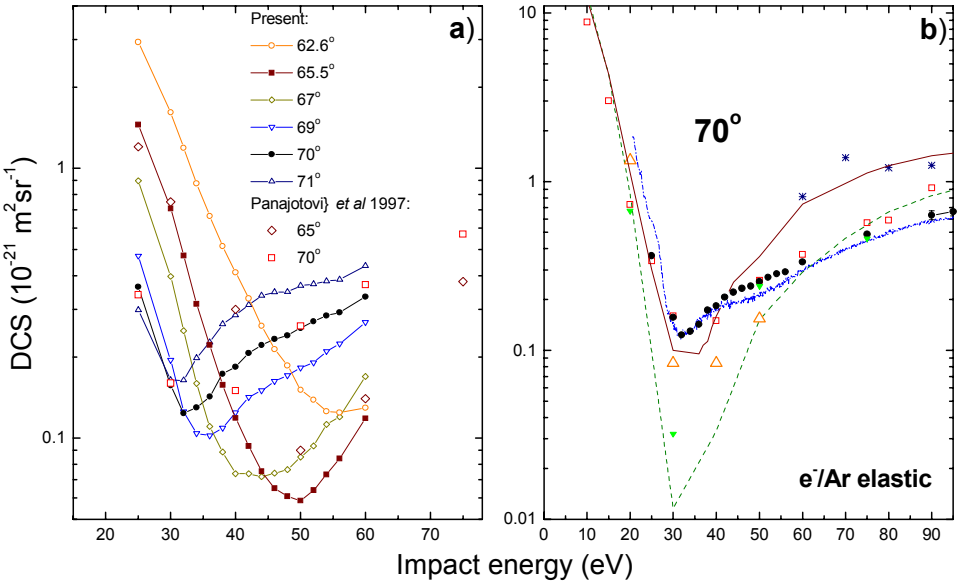

Fig. 2. *The energy dependent DCSs for elastic electron-argon scattering at various scattering angles in the vicinity of the low-energy critical points (a), and at 70° (b). References: present, ●; Panajotović et al 1997 [5], □; Cvejanović and Crowe 1997 [10], — ·—; Srivastava et al 1981 [15], ▼; Vušković and Kurepa 1976 [16], *; Williams and Willis 1975 [17], △; Sienkiewicz et al 2000 [7], ——; Fon et al 1983 [18], — —. The presented curves are obtained by connecting the points with straight lines.*

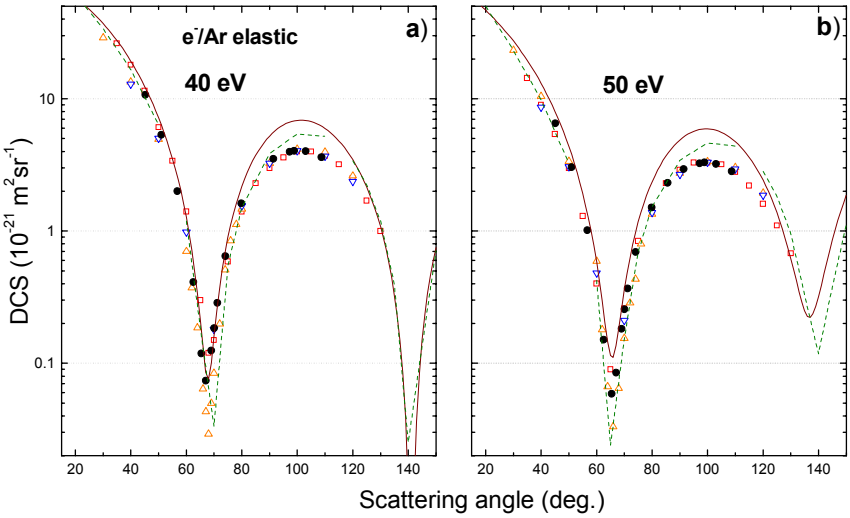

Fig. 3. *The angle dependent DCSs for elastic electron-argon scattering at 40 eV (a) and 50 eV (b). References: same as in figure 2, except for the Cvejanović and Crowe 1997 [10], ∇.*

High energies

There are very few published experimental results for elastic electron-argon scattering above 100 eV relevant for the investigation of the high-energy critical point, which should be expected between 100 eV and 150 eV. We have measured differential cross sections for elastic electron scattering by argon in the angular range from 40° to 126° in 5° increments (2° or 1° around minima) and energy range from 90 eV to 150 eV. Moreover, we have performed independent measurements of both angle dependent and energy dependent relative DCSs. This allowed us to use only one single point, i.e. the value of absolute differential cross section at one fixed energy and angle, for calibration of our data set. Present relative DCS at 100 eV and 100° was normalized with respect to the absolute DCS of Srivastava *et al* [15]. The absolute angle dependent DCSs at other fixed energies were obtained by using present experimentally obtained absolute normalized energy dependent DCS at 100°. The relative energy dependent DCSs at other fixed scattering angles were than normalized at the incident energy of 100 eV.

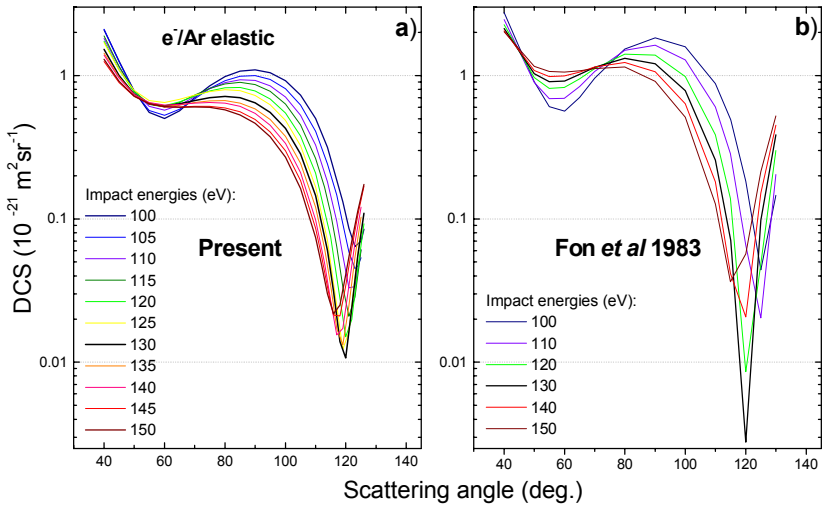

Fig. 4. *The angle dependent DCSs for elastic electron-argon scattering in the vicinity of the high-energy critical minimum: a) present results; b) Fon et al 1983 [18]. The presented curves are obtained by connecting the points (present experimental or previous published) with straight lines.*

In figure 4, present angle dependent absolute DCSs are presented, as well as the previous theoretical results of Fon *et al* [18] (figure 4b). Again, the same results, but as a function of incident electron energy at several fixed scattering angles, are presented in figure 5a. Moreover, these results are compared with the separate set of

DCSs, which were independently obtained as a function of incident electron energy. A very good agreement was achieved, considering experimental errors. In figure 5b, several energy dependent DCSs at 120° (present at 119.5°) are presented. There are few experimental results in the region between 100 and 150 eV and only the present one reveals the minimum that has been theoretically predicted. The minimum position of the theoretically obtained DCS by Sienkiewicz *et al* [7] is somewhat shifted towards lower energies. Nevertheless, in the insert in figure 5b, it could be seen that only at few degrees smaller scattering angles the agreement considerably improves. Finally, in figure 6a, one can see that the angle dependent DCS of Sienkiewicz *et al* [7] at 130 eV is slightly shifted towards lower scattering angles. This, however, is reflected as a rather large shift of energy dependent DCS (figure 5b).

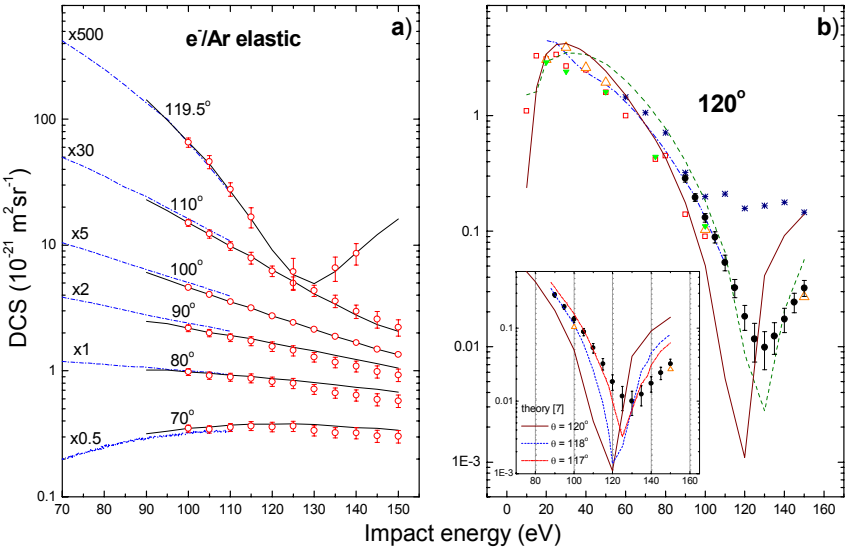

Fig. 5. *The energy dependent DCSs for elastic electron-argon scattering at various scattering angles. References: a) present angle dependent measurement, ○; present energy dependent measurement, ——; Cvejanović and Crowe 1997 [10], — · —; b) same as in figure 2.*

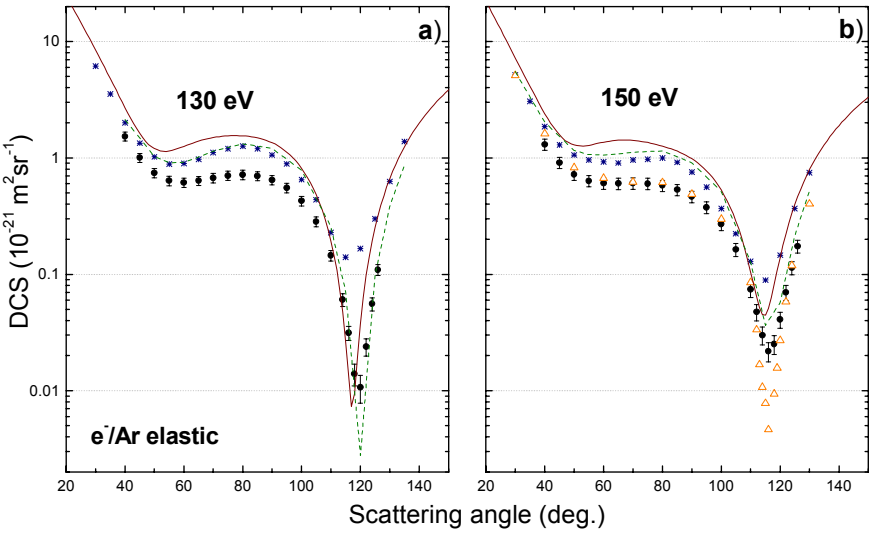

Fig. 6. *The angle dependent DCSs for elastic electron-argon scattering at 130 eV (a) and 150 eV (b). References: same as in figure 2.*

4. Conclusion

The detailed investigation of the behaviour of differential cross sections for elastic electron-argon scattering in the vicinity of two critical minima was performed. The relative angle dependent DCSs were measured in the vicinity of the lower-energy critical minimum from 30 eV to 60 eV in small increments of 2 eV, and normalized according to the energy dependent DCS at 100° of Cvejanović and Crowe [10]. Also, both angle

and energy dependent DCSs were measured separately in the vicinity of the higher-energy critical minimum from 90 eV to 150 eV. The calibration of this entire data set was obtained according to the one single point. The two sets of data, obtained either as a function of incident energy or scattering angle, are consistent, regarding experimental errors. The DCSs for elastic electron-argon scattering were presented as a functions of both incident electron energy and scattering angle. In addition, present results were compared to the available previous results at a few fixed incident energies and scattering angles. A very good agreement was achieved, although there are very few published experimental results for the electron-argon scattering between 100 eV and 150 eV. It was shown, however, that in the vicinity of critical points, even slight disagreement of different angle dependent DCSs could mean a large disagreement of the energy dependent DCSs.

5. References

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