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# 23<sup>rd</sup> Summer School and International Symposium on the Physics of Ionized Gases

August 28<sup>th</sup>-September 1<sup>st</sup> 2006, Kopaonik, Serbia

## CONTRIBUTED PAPERS

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ABSTRACTS of INVITED LECTURES,  
TOPICAL INVITED LECTURES and PROGRESS REPORTS

Editors:

Nenad S. Simonović  
Bratislav P. Marinković  
Ljupčo Hadžievski



Institute of Physics  
Belgrade, Serbia

23<sup>rd</sup> SPIG CONTRIBUTED PAPERS

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**ABSTRACTS OF INVITED LECTURES, TOPICAL INVITED  
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*Editors*

**Nenad S. Simonović, Bratislav P. Marinković and Ljupčo Hadžievski**

**Institute of Physics  
Belgrade, Serbia**

**Belgrade, 2006**

CONTRIBUTED PAPERS & ABSTRACTS OF INVITED LECTURES,  
TOPICAL INVITED LECTURES and PROGRESS REPORTS  
of the  
23<sup>rd</sup> SUMMER SCHOOL AND INTERNATIONAL SYMPOSIUM  
ON THE PHYSICS OF IONIZED GASES

28 August – 1 September 2006  
National Park Kopaonik, Serbia

*Editors*

**Nenad S. Simonović, Bratislav P. Marinković and Ljupčo Hadžievski**

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## PREFACE

This book contains the Contributed papers and abstracts of the Invited lectures, Topical invited lectures and Progress reports to be presented at the 23<sup>rd</sup> Summer School and International Symposium on the Physics of Ionized Gases – SPIG 2006. The symposium will be held in National Park Kopaonik, Serbia, from August 28 to September 1, 2006. The meeting is organized under the auspices and with the support of the Ministry of Science and Environmental Protection, Republic of Serbia. The conference is at the list of European Physical Society (EPS) sponsored conferences.

The Invited lectures and Contributed papers are related to the following research fields: Atomic Collision Processes, Particle and Laser Beam Interaction with Solids, Low Temperature Plasmas and General Plasmas. The length of Contributed papers is limited and each is supposed to present an original work with sufficient amount of scientific information. The Scientific and Organizing Committees believe that this conference manages to maintain the high scientific level of contributed papers and invited speakers in accordance with SPIG's long tradition.

The Editors would like to thank the members of the Scientific and Advisory Committees of SPIG 2006 for their efforts in proposing the invited lectures and progress reports, review of the contributed papers and selection of 12 papers for the oral presentation. We acknowledge the EPS sponsorships granted through East West Task Force scheme. Also, we are grateful for the support of our sponsors Kryooprema d.o.o. and EUnet d.o.o. Especially we acknowledge the support of all members of the Organizing Committee who contributed a lot to the preparing and running of the conference.

The participants have been asked to send their papers camera ready, so no typing, spelling and grammatical errors have been corrected in the course of preparation of this book. The Editors apologize for all mistakes that emerged from the software problems in the process of printing.

Finally we would like to thank all the invited speakers and the participants for taking part in this year's SPIG, to wish them to have a pleasant stay in Kopaonik, and to gain additional momentum and ideas for the future work.

Belgrade, August, 2006

Editors

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### **23<sup>rd</sup> SUMMER SCHOOL AND INTERNATIONAL SYMPOSIUM ON THE PHYSICS OF IONIZED GASES**

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# **SPIG 2006**

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  - 1.2. Heavy Particle Collisions
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# SPIG 2006

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# Measurements of Absolute Elastic and Vibrational Cross Sections for Electron Scattering from Tetrahydrofuran

A. R. Milosavljević<sup>1</sup>, I. Linert<sup>2</sup>, M. Dampc<sup>2</sup>, B. P. Marinković<sup>1</sup>, and M. Zubek<sup>2</sup>

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**Abstract.** We present preliminary results on electron collisions with tetrahydrofuran (THF) molecules in the gas phase at the energy of 10 eV. THF is considered to be the simplest prototype for investigations of electron interactions with deoxyribose molecules and the DNA sugar backbone. Differential cross section (DCS) for elastic electron scattering by THF was measured in the angular range from 20° to 180°. The absolute normalization of the DCS has been obtained by using relative-flow method with helium as a reference gas. The present elastic DCS agrees well with the most recent calculations of Trevisan et al. [*J. Phys. B: At. Mol. Opt. Phys.* **39**, L255 (2006)]. From the absolute DCS the elastic integral cross section is obtained and is compared with the recent measurements of the total cross section of Zecca et al. [*J. Phys. B: At. Mol. Opt. Phys.* **38**, 2079 (2005)]. Electron energy loss spectra in the energy loss region up to 1.2 eV and at fixed scattering angles were also measured. Using our elastic cross section, absolute DCS for excitation of mixture of the  $\alpha$ - and  $\beta$ -CH<sub>2</sub> stretch modes (measured energy loss of 351 meV) is obtained in the angular region 20°-180°.

**Keywords:** tetrahydrofuran, THF, elastic electron scattering, vibrational excitation.

**PACS:** 34.80.Bm, 34.50.Ez

## INTRODUCTION

The low- and medium-energy electron interaction with tetrahydrofuran (THF), C<sub>4</sub>H<sub>8</sub>O, molecules has attracted considerable attention in recent years. Majority of the recent studies were prompted by investigations of radiation damage to biological systems and a need to understand elementary electron driven processes in living cell, which are believed to be to a great extent responsible for most genotoxic effects. THF can be considered to be the simplest prototype for investigations of electron interactions with deoxyribose molecules and further with the DNA sugar backbone. Absolute cross section measurements for electron collisions with gaseous THF have only recently been reported. Here, absolute differential cross sections (DCSs) for elastic electron-THF scattering at incident energies from 20 eV to 300 eV [1] and total cross section (TCS) for electron (and positron) scattering below 21 eV [2] have been obtained. Very recently, the first theoretical papers on low-energy electron collisions

with THF have been published [3,4]. Bouchiha et al. [3] used R-matrix method to calculate integral elastic and electronic excitation cross sections (ICSs) in the energy region up to 10 eV. Trevisan et al. [4] used complex Kohn variational method to calculate momentum transfer cross section and elastic DCSs in the region up to 20 eV. To the best of our knowledge, there are no experimental DCSs for elastic electron-THF scattering below 20 eV. On the other hand, several studies on vibrational and electronic excitation of THF in both gas and solid phases have been reported. Lepage et al. [5] were mainly focused on electron spectroscopy of resonance-enhanced vibrational excitation of THF condensed on Pt (see [5] for other references). However, measurements of the vibrational DCSs for THF have not yet been presented.

## EXPERIMENTAL

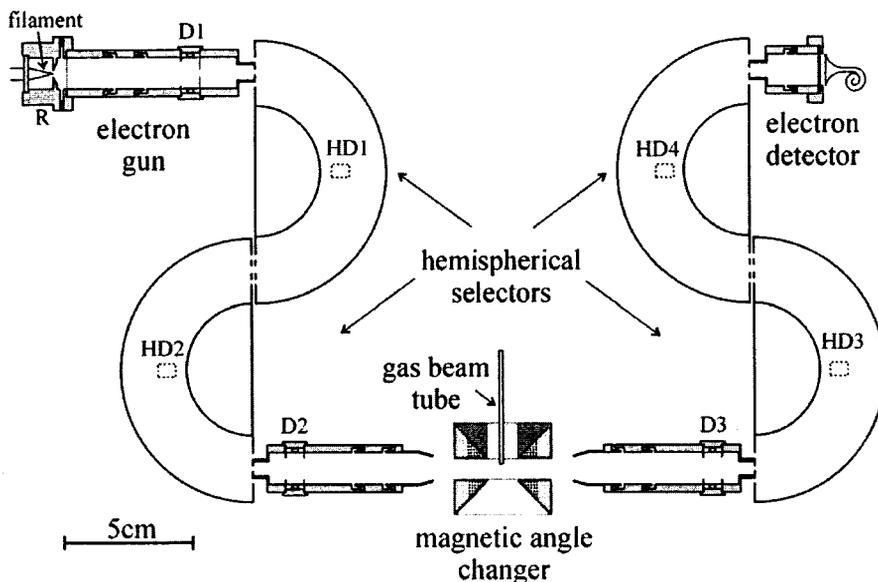


FIGURE 1. Schematic drawing of the hemispherical electron spectrometer [6].

The measurements were performed on the hemispherical electron spectrometer [6] at Gdańsk University of Technology. In the spectrometer (Figure 1), both monochromator and electron energy analyzer of the spectrometer incorporate two hemispherical energy selectors arranged in series and are equipped with systems of cylindrical lenses and deflectors. The incident electron beam is crossed at right angle with a target gas beam produced by a stainless still needle. The scattered electrons are detected by a single channel electron multiplier. The electron analyzer can be rotated around the target gas beam in the angular range from about  $-10^\circ$  to  $90^\circ$ . The range of accessible scattering angles is further extended into backward scattering, up to  $180^\circ$  by using magnetic angle-changer. The angular scale was calibrated against positions of minima in the DCSs for elastic electron scattering in argon. The angular resolution of the spectrometer is estimated to be  $5^\circ$ . The incident electron energy scale was

calibrated with respect to positions of the  $^2P_{3/2}$  resonance in argon at 11.098 eV. In the present measurements the overall energy resolution of the spectrometer was 80-90 meV. The experimental system allows measurements of the absolute DCSs using relative-flow method. The anhydrous THF was purchased from Aldrich with a declared purity >99.9% and was used after a few freeze-thaw cycles under vacuum.

In the measurements of the absolute elastic DCS the scattering intensity was measured at the maximum of the elastic peak as a function of the scattering angle. Relative elastic DCS was derived from the measured intensities by applying effective scattering volume correction obtained from elastic electron scattering in helium. This relative DCS was next normalized to absolute values obtained at the selected scattering angles by using relative-flow method with helium as a reference gas. To obtain ICS, the absolute DCS has been extrapolated down to  $0^\circ$  and integrated in the whole angular range  $0^\circ$ - $180^\circ$ . The absolute DCS for excitation of mixture of the  $\alpha$ - and  $\beta$ - $\text{CH}_2$  vibrational stretch modes (energy loss peak at 351 meV) has been obtained in the range  $20^\circ$ - $180^\circ$  using vibrational to elastic intensities ratios which have been determined from energy loss spectra measured at fixed scattering angle.

## RESULTS AND DISCUSSION

The absolute DCS obtained at 10 eV for elastic electron-THF scattering is shown in Figure 2. The results of the most recent calculations of Trevisan et al. [4], obtained using the complex Kohn variational method are also shown for comparison. There is good overall agreement between our measurements and calculations, although the calculated DCS is somewhat higher above  $80^\circ$  and do not show a minimum at about  $90^\circ$ . From our experimental DCS we obtain the ICS for elastic electron scattering at 10 eV equal to  $32.9 \times 10^{-20} \text{ m}^2$ . This is in a good agreement with the TCS of about  $35 \times 10^{-20} \text{ m}^2$ , which we have estimated by interpolation of the experimental results of Zecca et al. [2].

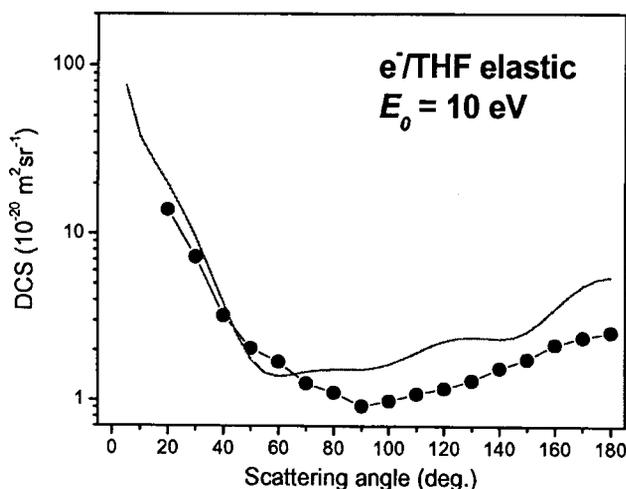
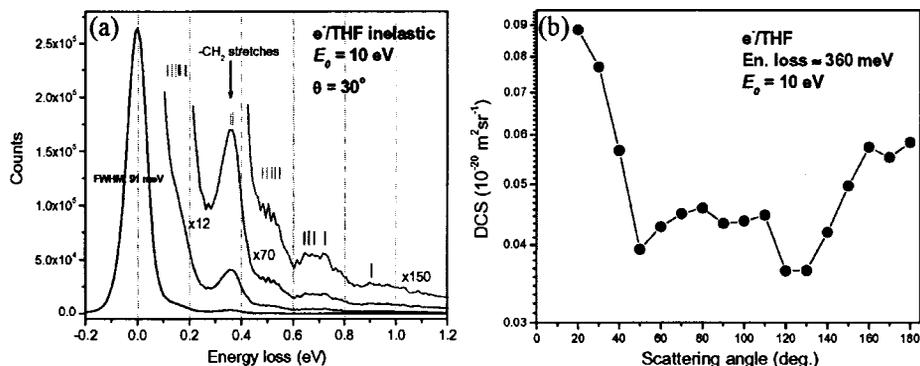


FIGURE 2. Absolute differential cross sections for elastic electron scattering from THF at the incident electron energy of 10 eV: •, present experiment; ---, calculations of Trevisan et al. [4].

An energy loss spectrum obtained for THF at the incident electron energy of 10 eV and a scattering angle of  $30^\circ$  is shown in Figure 3a. We marked positions of the fundamental vibrational modes [5] and overtones of the fundamental modes together with combination modes which are most likely excited. The clearly resolved peak at 351 meV corresponds to a mixture of  $\alpha$ - and  $\beta$ -CH<sub>2</sub> stretch modes. The absolute DCS for excitation of this group of vibrational modes is given in the Figure 3b.



**FIGURE 3.** (a) An energy loss spectrum of THF recorded at an incident electron energy of 10 eV and a scattering angle of  $30^\circ$ . (b) Absolute differential cross section for excitation of the group of  $\alpha$ - and  $\beta$ -CH<sub>2</sub> stretch modes at 351 meV.

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