# THE NEGATIVE ION PROJECT AT CRYRING

K. Andersson and D. Hanstorp
*Department of Physics, Chalmers University of Technology/Göteborg University, SE- 412 96 Göteborg, Sweden*

A. Neau, F. Hellberg, S. Rosén, H. Schmidt, J. Semaniak, R. Thomas and M. Larsson
*Department of Physics, Stockholm University, P. O. Box 6730, SE-113 85 Stockholm, Sweden*

A. Le Padellec
*LCAR UMR 5589 Universite Paul Sabatier-Toulouse III 118, route de Narbonne Bât. III R1, b4 31062 Toulouse cedex 4, France*

D. J. Pegg
*Department of Physics, University of Tennessee, Knoxville, Tennessee 37996, USA*

H. Danared, A. Källberg and F. Österdahl
*Manne Siegbahn Laboratory*

## Introduction

Negative ions are interesting from a fundamental point of view. In such loosely bound systems, the normally dominant Coulomb interaction is suppressed and the interelectronic interaction can become greater than the interaction of each electron with the rest of the system. Under such conditions the independent particle model, that adequately describes atomic structure under normal conditions, breaks down. Experimental studies of negative ions can therefore serve as a probe of electron correlation effects and hence be used to test theoretical models in order to better understand atomic and molecular processes.

To date, most information on the structure of negative ions has been obtained by studying the photodetachment process, in which the outermost electron is ejected following the absorbtion of a photon. Pioneering experiments were carried out by Branscomb in the 1950's. Lineberger and co-workers in the 1970's [1] performed the first systematic studies of photodetachment. By using neutral particle detection as well as electron spectroscopy, they managed to determine the ground state configuration of most atomic, and some, molecular negative ions. In more recent years, the combination of photodetachment and resonance ionisation spectroscopy has been shown to be a powerful tool for studies of bound as well as continuum states [2-3]. Studies of the interaction between negative ions and electrons have been carried out by Tisone and Branscomb [4-5], by Dance, Harrison and Rundel [6] and later by Peart, Walton and Dolder [7]. After storage ring technology came into operation, a number of studies were performed by Andersen and collaborators [8] using the storage ring ASTRID (Aarhus University - Denmark).

## Technical development

The negative ion project at CRYRING was initiated in the spring of 1999. As a first test, the existing MINIS ion source was used to produce F- ions. These ions were injected and accelerated to full energy (5.05 MeV) and velocity compressed in the electron cooler. The outcome of this test was very positive. The storage time at full energy was 6.0 s, which is sufficient in order to perform a wide range of photodetachment and electron impact studies.

After the successful injection into the ring a new, dedicated ion source was purchased and installed by the Manne Siegbahn Laboratory. It is a Sputter Ion Source manufactured by Peabody Scientific [9]. In this source positive cesium ions are accelerated towards a cooled solid target. The cesium vapour in the source condenses to form a few monolayers on

the cathode. Atoms or molecules sputtered from the target will then, with a rather high probability, capture electrons from the cesium layer and hence leave the source as negative ions. By a proper choice of the cathode material, almost any atomic ion, and many molecular ions, can be produced. This source is now routinely used. Among the ions produced are $F^-$, $S^-$, $CN^-$ , $C_4^-$ and $Cl^-$.

## Results

*Electron impact detachment of halogen negative ions*

The properties of a plasma are strongly dependent on whether the negative charge is carried by the highly mobile electrons or the slower moving negative ions. In order to correctly model a plasma, it is therefore important to know the cross section for collision processes involving negative ions. The destruction of negative ions due to electron impact is one of the most important processes. One example of an application where this process is of importance is in plasma etching in the semi-conductor industry, where halogens often are used as an active reactant. Another example is in excimer lasers where metastable excimer molecules are formed by attaching a neutral halogen atom to an excited noble gas atom. If the halogen is negatively charged it will not be able to participate in the laser action. Modelling of such lasers therefore requires accurate values of cross sections for production and destruction of negative halogen ions.

In our first experiment on negative ions at CRYRING, we studied one such process, namely electron detachment of $F^-$. The results of this study have been recently published in the European Journal of Physics [10]. Later, we studied electron impact detachment of $Cl^-$.

## Detachment and dissociation of $CN^-$

The first molecular anion we chose to study was $CN^-$. The electron affinity of this stable molecule in its ground state configuration $(5\sigma)^2(1\pi)^4$ is 3.821 eV. In the experiment, negative ions were stored in the ring and collided with electrons in the electron cooler. Neutral fragments arising from detachment and/or dissociation processes were detected with a surface barrier detector placed 3.5 meters downstream to the interaction region. Positive fragments were detected with another, similar detector placed on the path taken by ions being bent out of the ring. A grid technique was applied in order to distinguish the detachment channel

$$CN^- + e^- \rightarrow CN + 2e^-$$

from the detachment and dissociation channel

$$CN^- + e^- \rightarrow C + N + 2e^-$$

In total, 8 different decay channels where investigated. Our main conclusion from this experiment is that the pure detachment channel completely dominates over all other energetically allowed channels [11].

## Detachment and dissociation of $C_4^-$

The $C_4^-$ cluster ion was chosen for the second experiment on molecular negative ions. The four curves shown in fig. 1 represent the cross sections for production of the four neutral fragments $C_4$, $C_3$, $C_2$ and C. Again, the experiment clearly shows that

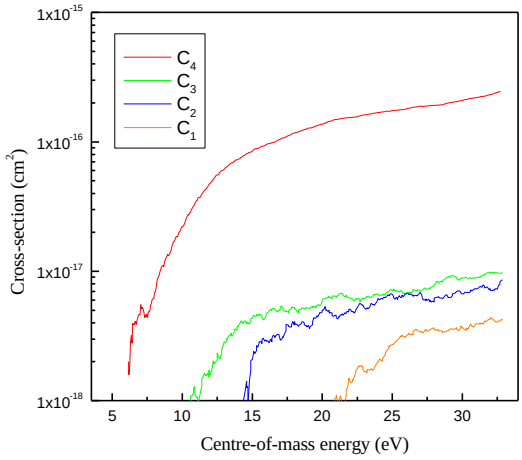


Fig.1 Cross sections for the production of the neutral fragments, $C_4$, $C_3$, $C_2$ and C. The small structure at 7.5 eV in the $C_4$ cross section is identified as a resonance arising from the decay of a short lived state of the doubly charged negative ion, $C_4^{2-}$.

pure detachment is the dominant break-up process. Perhaps the most interesting outcome of the experiment is, however, the observation of a structure in the threshold region of the $C_4$ channel. We interpret this as arising from the decay of a transient resonance state of the doubly charged negative ion, $C_4^{2-}$. The measured width of the resonance corresponds to a lifetime of approximately 0.7 ps. The energy of this state is

above the ground state of the neutral molecule $C_4$ making it energetically possible for the state to spontaneously autodetach, ejecting two electrons in the process.

## Conclusion and outlook

This project has now come to the stage where the technical problems associated with producing, injecting and accelerating negative ions into CRYRING have been solved. In the future we intend to study a variety of processes, including electron impact experiments on atomic, molecular and cluster negative ions and laser photodetachment experiments on atomic ions.

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