4.4 THE NEGATIVE ION PROJECT AT CRYRING

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4.4.1 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 becomes 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 the electron correlation effect and hence be used to test theoretical models in order to get better understanding of atomic and molecular processes.

Most information on the structure of negative ions has been obtained by studying the photodetachment process, in which the outermost electron is emitted due to the absorbtion of a photon. Pioneering experiments were carried out by Branscomb in the 1950's, but it was Lineberger and co-workers in the 1970's [1] that performed the first systematic studies. By using neutral particle detection and 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 interaction between negative ions and electrons, on the other hand, have been carried out by Tisone and Branscomb [4-5], by Dance, Harrison and Rundel [6] and later by Peart, Walton and Dolder [7]. Later, after the 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).

4.4.2 Technical development

The negative ions 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 cesium 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 forms 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 atoms and hence being emitted as negative ions. By a proper choice of the cathode material almost any atomic and many molecular ions can be produced. As an example, CN^- ions were produced in a cathode consisting of a mixture of graphite and boron nitride powder and pressed into a hollow copper cathode.

4.4.3 Results

4.4.3.1 Electron impact detachment of halogen negative ions

The properties of plasma are strongly dependent on whether the negative charge is in the form of highly mobile electrons or slowly moving negative ions. In order to correctly model 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 then one of the most important processes. One example of an application where this process is of importance is in plasma etching in 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 in the negative charge state 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^-. Figure 1 shows the relative cross section in the energy range 0–60 eV. We have also taken data in order to obtain an absolute cross section, but that data has at present time not been analysed. The onset of the process is determined to be 8 eV, i. e. substantially larger than the electron affinity of fluorine. This is caused by coulomb repulsion between the electron and the F^- ion. It is our intention to continue with the corresponding studies for the heavier halogen negative ions.

4.4.3.2 Detachment and dissociation of CN^-

As a first molecular anions we choose to study CN^-. The configuration $(5\sigma)^2(1\pi)^4$ of this molecule makes it very stable, with an electron affinity of 3.821eV.

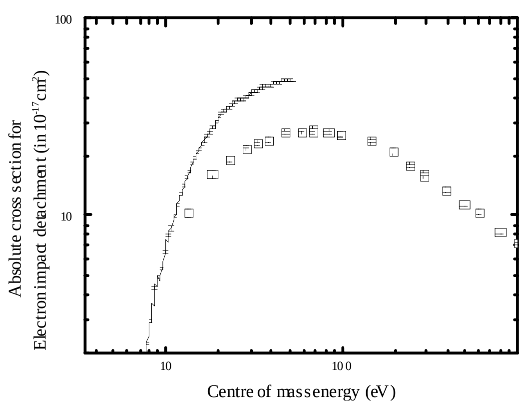

Fig. 1. The full line is our relative cross section measurements. For comparison the curve is placed in the same figure as the absolute values obtained by Peart et al (1979).

In this experiment, negative ions stored in the ring collided with electrons in the electron cooler. Neutral fragments caused by 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 trajectory for positive ions, i. e. a path bending out of the ring. The so-called grid technique was further 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. This experiment was performed just prior to the completion of this report, and we are now in the process of evaluating the data in order to deduce cross sections and branching ratios.

4.4.4 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. The two first experiments have just been completed and we are in the process of analyzing the results. During the years to come we intend to perform a long range of studies, including electron impact experiments of molecular and atomic negative ions and laser photodetachment experiments directed towards atomic systems.

4.4.5 Acknowledgement

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4.4.6 References

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