Neutral C_{60} effusive source for atomic collisions with fullerene

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A neutral C_{60} effusive source was assembled in a crossed molecular-beam apparatus in order to perform atom–molecule electron transfer collisions and its calibration by time-of-flight mass spectrometry. This source consists of a stainless-steel oven where the C_{60} sublimation takes place. Typical operation temperatures are in the range of 723 up to 888 K. Through this setup the study of the ion pair formation process $K+C_{60}\rightarrow K^{+}+C_{60}^{-}$ (where K is a potassium atom) can be performed in a wide range of collision energies (10 up to 500 eV). The results show evidence of negative ion formation (being the ratio of intensities between the parent ion and fragment ions) clearly dependent on the collision energy used. © *2001 American Institute of Physics.* [DOI: 10.1063/1.1396662]

I. INTRODUCTION

Taking profit of vacuum technology, a wide range of molecular-beam experiments can be performed, providing a main support for the development of molecular physics and beam technology.[1]

Effusive C_{60} sources have been used in the last decade for depositing thin films, and particularly, a rather sophisticated one with an accompanying mass spectrometer, was developed by Budrevich, Tsipinyuk, and Kolodney.[2]

Using a crossed molecular-beam setup configuration,[3] a simple and compact neutral C_{60} effusive source, powered by a thyristor unit, was built and assembled in the collision chamber, in order to produce a C_{60} neutral flux focused in the collision volume. This source consists of a stainless-steel oven, capable of reaching temperatures up to 1073 K. To assure the nonexistence of temperature gradients along the oven, a previous simulation study based on a finite code algorithm was done using MATLAB. Once the thermal equilibrium is reached the C_{60} neutral beam possesses a well-defined internal energy distribution, since the molecules effuse in the molecular flux regime.

Such a C_{60} beam intersects at 90° a fast hyperthermal flux of neutral potassium atoms, formed in a resonant charge exchange source described by Aten and Los.[4] In the alkali atom–molecule collision the negative ionization of the molecular target is induced through electron transfer, where the potassium atom donates the electron to the molecule. Depending on the collision energy, parent ion fragmentation is expected to occur.

II. EXPERIMENT

The experimental setup developed for performing the measurements has been already described elsewhere.[3] The oven was heated up making use of four electrical resistances, and the heating power supplied by a thyristor unit ($I_{max}=63$ A, $V_{max}=500$ V). The C_{60} neutral beam was captured by a cryogenic pump operating at 18 K located in front of the oven. Through this pumping eventual molecular reflection by the chamber internal walls is avoided and so noise in the collision volume is reduced. Due to the high temperatures in which the C_{60} oven operates, it was necessary to assemble a thermal shielding, which consists of two concentric high-polished stainless-steel sheets. Its efficiency was verified via temperature measurements in the close neighborhoods. The temperature measured on the external surface of this shield was about a factor of 2.6 less than that of the oven.

The highest temperature used in the experiments was 888 K, since according to the oven geometry, above such a temperature the molecular flux condition is violated. The C_{60}

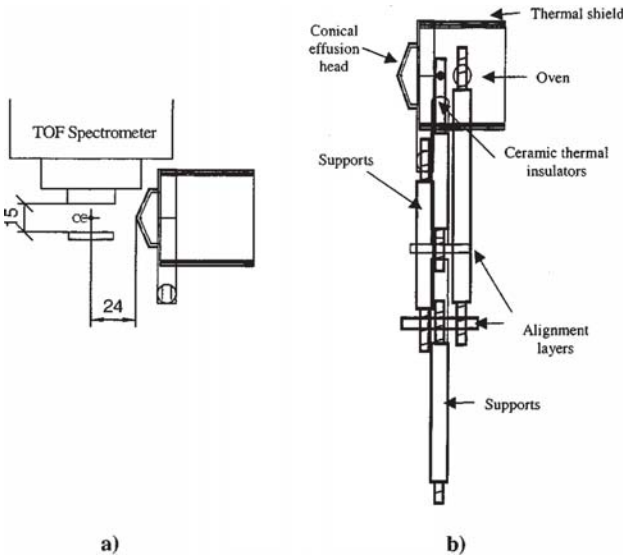

FIG. 1. Schematic views of the oven's position: (a) near the TOF spectrometer [distance to the collision center (CC) in millimeters] and (b) its complete structure, including supports and thermal shielding.

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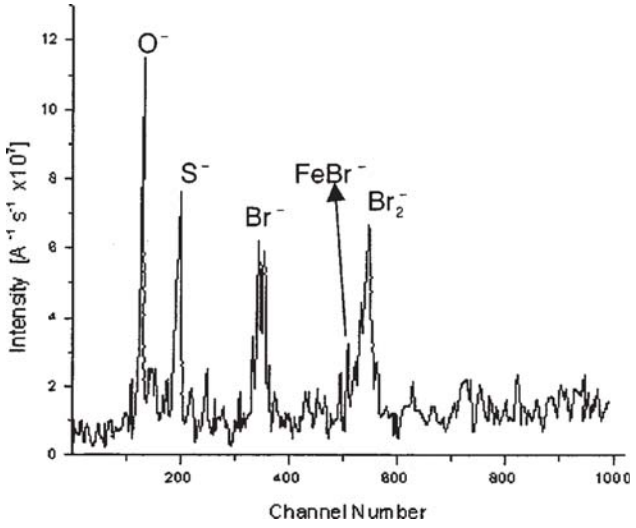

FIG. 2. Time-of-flight spectrum for the $K+FeBr_2$ collision.

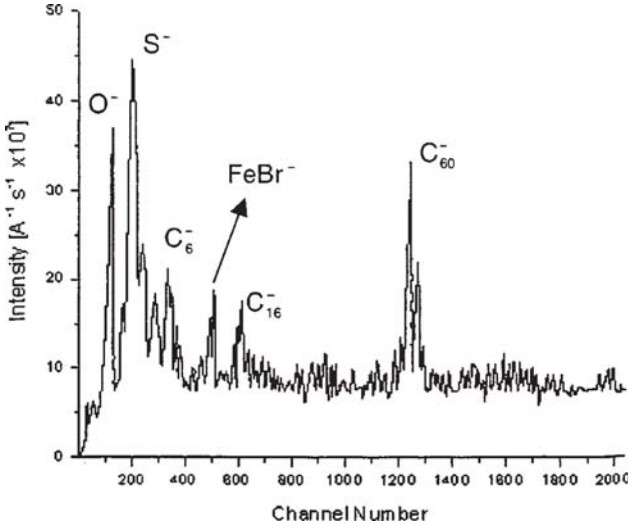

FIG. 4. Time-of-flight spectrum obtained at high energy, for a center of mass energy of 78.66 eV. The temperature of the oven was also 843 K.

molecules effuse through a 0.5-mm-diam orifice, which results in an estimated flux of 2.4×10^{12} molecules s^{-1} cm^{-2} at the collision center. In Fig. 1, a schematic view of the oven and its assemblage in the collision chamber are shown. The negative species formed in the interaction region were extracted by an electric field pulse, 2.0 μs long in a 100 μs duty cycle, and accelerated into a two drift region time-of-flight (TOF) mass spectrometer with a total flight path of 27.5 cm. In the first region species were accelerated up to 65 eV and in the second one up to 800 eV. Finally, they were accelerated up to 1200 eV and detected with a channel electron multiplier. Data acquisition was carried out on a 2046 channel multichannel analyzer working in the pulse-height analysis (PHA) mode. The TOF spectra were obtained after a certain accumulation time, which was enough to assure good statistical behavior. A previous calibration of the TOF spectrometer was done using solid impure $FeBr_2$ as the precursor of the target beam. This corresponding TOF spectrum is displayed in Fig. 2 and shows Br_2^-, Br^-, and $FeBr^-$ formation. Due to the oxide and sulphur contamination of this sample, also S^- and O^- ions were detected.

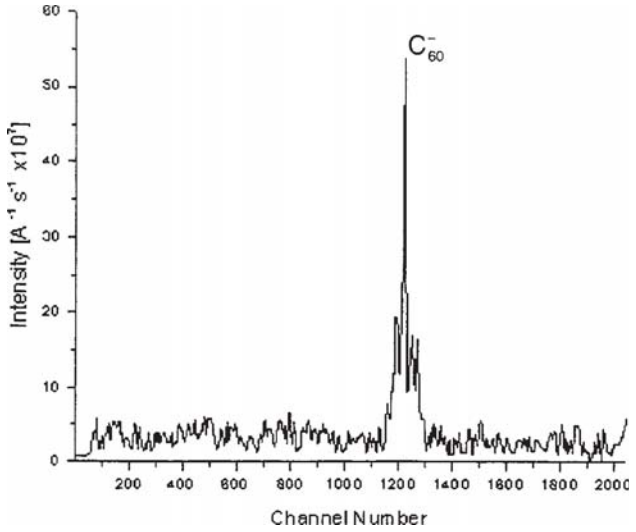

FIG. 3. Time-of-flight spectrum obtained at low energy. The center of mass collision energy was 9.74 eV and the C_{60} oven's temperature 843 K.

III. RESULTS

In the $K+C_{60}$ collision the results show evidence of parent negative ion formation (Figs. 3 and 4). At low energies only this contribution comes out; however, when increasing the collision energy additional fragmentation is observed. Negative ionic fragmentation at a center of mass collision energy of 79 eV includes C_6 and C_{16} anions, although at this collision energy C_{60}^- is also present. Taking account of these preliminary results, the presence of other negative charge fragments is not excluded.

IV. DISCUSSION

From the experimental results one can infer that the constructed source produces a neutral beam of C_{60} molecules. This oven thus provides the possibility of a detailed study on the $K+C_{60}$ collision dynamics. The collision-induced electron transfer technique used in this work allows us to perform the study of negative fragmentation of the fullerene anion, which cannot be observed through electron attachment techniques.[5]

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