Cluster Effects on Charge State Distributions for Heavy Ion Molecular Beams*

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The charge state distributions of ions emerging from carbon foils were compared for equal velocity monoatomic and polyatomic negative ions incident on the foil. Such comparisons were performed for O_2^- vs O^- using foil thicknesses from 1 to 55 $\mu g/cm^2$ and for C_3^- vs C^- and C_4^- vs C^- using a single foil thickness of 1 $\mu g/cm^2$. The experimental arrangement is shown in Fig. 1. A monitor detector close to the target and a digital current integrator used for the carbon measurements are not shown. The carbon measurements were performed in collaboration with H. E. Wegner in conjunction with the stereo-chemistry experiments reported elsewhere in these proceedings. Figures 2 and 3 show measured charge state distributions for carbon and oxygen, respectively, and Fig. 4 shows how the observed effect varies with foil thickness for the oxygen case. In all cases, the distribution is shifted towards lower average charge states for the molecular beams and the effect persists, even though attenuated, up to and including the thickest foils used.

The most straightforward interpretation of these results is similar to the interpretation of the cluster effect for neutral hydrogen production from H_2^+ ions.¹ Namely, that for each component of the cluster there are more correlated electrons available for pickup than for single ions. A comparison of these results to those of hydrogen shows that the effect is

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much larger because it clearly manifests itself in the average charge state rather than in the rare neutral fraction and because it persists much longer as a function of foil thickness or dwell time. Also, no short-dwell-time effect is observed which would have been of opposite sign to that for positive molecules.

The interatomic distance (R_{AB}) distribution at the foil exit was estimated for the O_2^- experiments. Figure 5 shows the results of a Monte Carlo-type computer simulation in which the foils were divided into thin layers and only uncorrelated multiple scattering was considered in each layer while a screened Coulomb explosion was superimposed for the curve shown in Fig. 6. (Multiple scattering is observed to play a dominant role in the thicker foils.) Figures 7a and 7b show the fraction of pairs emerging within the atomic distances R_{AB} smaller than 5 and 10 Å, respectively. In each case, the lower curves correspond to the calculation with Coulomb explosion included. If the average interatomic distances for the thickest foils are as large as indicated, then the persistence of the observed effect with increasing thickness seems surprising and difficult to understand.

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REFERENCES

1. M. J. Gaillard, J. C. Poizat, A. Ratkowski, J. Remillieux, and M. Auzas, Physical Review A 16, number 6, 2323 (1977).

FIGURE CAPTIONS

- Fig. 1 Schematic diagram of the experimental setup.
- Fig. 2 Measured charge state distributions for C_3^- and C_4^- beams incident on $1 \mu\text{g}/\text{cm}^2$ carbon foils compared to distributions obtained with C^- incident beams of the same velocities.
- Fig. 3 Measured charge state distribution for a $3.36 \text{ MeV } O_2^-$ beam incident on a $2 \mu\text{g}/\text{cm}^2$ carbon foil compared to the distribution obtained with a O^- incident beam of the same velocity.
- Fig. 4 Variation with foil thickness of the difference between average charge states for O_2^- and O^- incident beams for constant exit velocity. The black dot indicates the result of a test measurement in which a $10 \mu\text{g}/\text{cm}^2$ foil was replaced by two $5 \mu\text{g}/\text{cm}^2$ foils 1 mm apart. As expected the effect disappears.
- Fig. 5 Calculated probability distributions of interatomic distances at the foil exit for three foil thicknesses with $210 \text{ keV}/\text{amu } O_2^-$ incident beam. Only uncorrelated multiple scattering was considered.
- Fig. 6 Calculated probability distributions of interatomic distances at the foil exit for three foil thicknesses with $210 \text{ keV}/\text{amu } O_2^-$ incident beam. A screened Coulomb explosion and uncorrelated multiple scattering were considered.
- Fig. 7 Calculated fractions of clusters emerging with interatomic distances smaller than $5 \text{ \AA}$ and $10 \text{ \AA}$ as functions of foil thickness for $210 \text{ keV}/\text{amu}$ incident O_2^- beams. The upper curves correspond to only uncorrelated multiple scattering and for the lower ones the effect of a screened Coulomb explosion has been included.

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fig. 3

fig. 4

Probability
(arbitrary units)

fig. 5

Probability
(arbitrary units)

10 mg/cm²

30 mg/cm²

50 mg/cm²

10

20

30

40

50

RAB(μ)

fig. 6

fig. 7 a

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