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MEASUREMENTS OF METAL ATOM AND CLUSTER POLARIZABILITIES

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Abstract
A new technique to measure the polarizabilities of atoms and small clusters of refractory metals in a molecular beam is described. Clusters are produced in a laser vaporization source and the collimated cluster beam is deflected in an inhomogeneous electric field. The clusters are then photoionized and detected by a recently developed position sensitive time of flight mass analyzer. The polarizabilities are calculated from the measured deflections. We have measured for the first time the polarizabilities of the the aluminum atom and the aluminum dimer for which we find $6.8 \pm 0.3\ 10^{-24}\ cm^3$ and $19 \pm 2\ 10^{-24}\ cm^3$ respectively.

Introduction

Experimental values for the polarizabilities of clusters are of fundamental importance. For small sodium clusters the polarizability is approximately $(R + \delta)^3$ (1), where R is the classical radius and δ is the electronic spill out factor. For these clusters it is found that δ is approximately constant for all sizes from the atom to the bulk. Since the static polarizability is a ground state property, it can be accurately calculated and is a good test of electronic structure calculations. However, because of difficulties in producing molecular beams of refractory materials, the atomic polarizabilities of relatively few elements have been measured.

Experimental Method

Clusters are produced in a laser vaporization source (1). The inert gas carried cluster beam is collimated and passes between the two electric field plates which produce a field gradient of about 1150 kV/cm2 at a field of 220 kV/cm. Due to this field the clusters are deflected on the order of 0.5 mm at the detector which is located 1m from the field plates. The total distance from source to detector is 2.4 m. The deflections are given by $d = \alpha g V^2/mv^2$, where α is the polarizability, V the plate voltage, m the cluster mass, v the cluster velocity, and g is a geometrical factor.

In the detector the clusters are ionized with a UV light pulse from an eximer laser. The clusters ions are accelerated perpendicular to the molecular beam by uniform electric fields. These fields are adjusted so that the flight time of a cluster depends on its mass as well as on its position at the time of ionization. A shift of 1mm in the position of the cluster causes a shift of about 0.1% in its flight time. One can therefore determine the deflections of the clusters caused by the inhomogeneous electric field. The ratios of the deflections of the clusters are then directly proportional to the ratios of the polarizabilities.

Results

From the deflections we find that the ratio of the polarizability of the aluminum atom and the lithium atom is 0.284 and the ratio of the aluminum dimer and the aluminum atom is 2.77. Using the measured value for the lithium atom we then find for the polarizabilities of the aluminum atom and the aluminum dimer $6.8 \pm 0.3\ 10^{-24}\ cm^3$ and $19 \pm 2\ 10^{-24}\ cm^3$ respectively. These values agree well with recent calculations by I.Moullet who finds 6.67 and 17.39 $10^{-24}\ cm^3$ (2). Measurements for larger clusters up to about Al 50, and of atoms of refractory metals are currently being performed.

References

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2) I. Moullet, private communication (1989).