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ELECTRON INTERACTION WITH METALLIC CLUSTERS

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Abstract

we re-analysized the inelastic cross sections of low energy electrons colliding with metallic clusters. The analysis indicates that polarizability may take two forms in the low electron energy region. The low-energy region follows the static polarizability expression of Langevin. At higher energies, however, dynamical form comes into play. The full explanation of the obtained inelastic cross section seems to require both form of polarizability to be taken into account.

Key words: Metallic cluster, Polarizability

1. GENERAL REMARKS

Metallic cluster is characterised by delocalized electrons, which tend to possess symmetrical charge distributions, especially around the magic numbers. The high deformability of charge distributions leads to producing dipole readily [1]. In the photoabsorption cross-sections measurements this appears as a giant resonance structure [2-3]. The polarizability has also become a subject of theoretical and an experimental studies of low energy electron interactions with metallic clusters later, its significance in collision process is explained in the various studies [4-6].

The studies reported so far for the low-energy electron interactions with metallic clusters have led to recognising the rule of two forms of polarizability, namely statical and dynamical polarizability. The static form of polarizability has been reported in most collision studies for the metallic clusters (see [4] and references therein). An experimental study we reported pointing out the dynamical form of polarizability [5]. In this report, we emphases that both form of the polarizability may contribute to the inelastic cross section in the low electron energy region.

2. ANALYSIS OF DATA

Let us describe the experimental set up before getting into the data. The set up consist of a two-temperature as a cluster source, time of flight system where mass separation of the ionized clusters was performed, and MCP (Microchannal plates) detector via that the ions are collected.

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Cluster sizes, namely K_n ($8 \geq n \geq 3$), were studied with this system [5]. Of the clusters, the K_8 cluster is considered in here. The obtained inelastic cross section for the K_8 is given in Figure 1. Two characteristic features appear from the data. The first one is the general behaviour in the studied energy range that is proportional to the inverse square root of the incoming electron energy. Secondly, the resonance structures at energies around 1.5 eV and 3.25eV are superimposed on this base line.

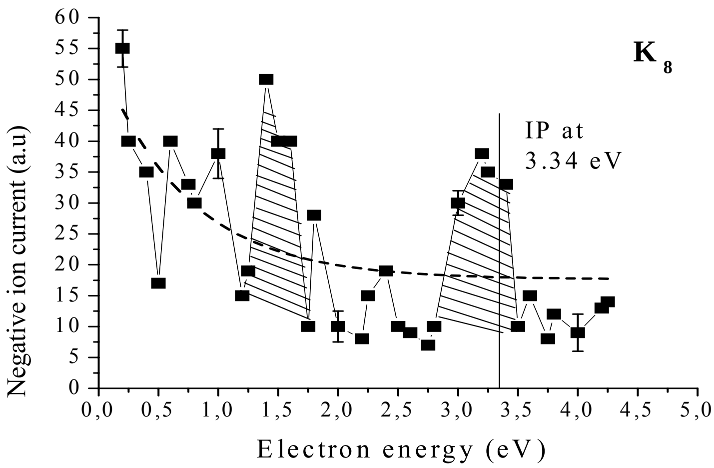

Figure 1 Electron attachment spectrum of K_8 cluster. A dashed curve is a polynomial fit to data, showing general decrease in signal strength with increasing energy. The measured ionization threshold (Sanundres et al 1985) is shown with a vertical bar. The shaded peaks are the ones we identified as resonances (from ref. 5).

The general behaviour can be explained via classical Langevin approach [7], in which an electron approaching a neutral cluster polarises it and is subsequently attracted by the induced polarisation potential [4]. The classical expression for the cross-section of electron capture is as

$$\sigma_{orb} = \pi \left\{ \frac{2\alpha e^2}{E} \right\}^{1/2}$$

where the E is the kinetic energy of incident electron and α is the polarizability that is treated as a constant. This predicts that the inelastic cross-section changes with the inverse square root of energy. Although the approach does not explain the resonance structures, may be considered as a weak point, the prediction of which for the inelastic cross section is in agreement with observed behaviour of the data. As can be seen from the figure, the agreement is clear for the energy range up to around 1.25 eV. The agreement is also consistent with the other cluster sizes studied as well as the studies reported for the inelastic cross section measurements of the metallic clusters. This indicates that polarizability may possess statical form in this region.

The resonance structures at energies around 1.5 eV and 3.25 eV have been explained in our previous publication [5]. Briefly, the former is due to the dynamical effect of polarizability while the latter one comes from the electron capture to quasi discrete level and an excitation of collective resonance. The studies reported consider the region above 1eV as a direct fragmentation region [4] and references therein. The essential question to investigate is: how does the fragmentation take place? Fragmentation can take place directly or through an evaporation process (cluster heating). In direct fragmentation, the large part of the incoming electron energy is transferred to a single atom or a small fragment and the rest recoils. For this, theoretical and experimental studies are not available in detail yet for alkali clusters [8]. The explanation is provided through dissociation energies of the target cluster [1]. The latter implies the sharing of excitation energy between all the vibrational degrees of freedom and it is followed by the evaporation of fragments. It has been predicted that the fragmentation follows collective or giant resonances for alkali clusters [9-10]. In the light of these findings we could say that in the region above the 1.25 eV, polarizability may have dynamical form.

3. CONCLUSION

On the bases of the experimental data along with Langevin approach, the polarizability can be in the static form at energies less than 1eV, while the polarizibility may take the dynamical form around 1.25 eV, which leads to a ‘giant resonance’. The static polarizability explains the initial part of the cross-section. For the other part of the spectrum, dynamical polarizability needs to be taken into account. This conclusion, however, requires more mass-selected data for both small and large clusters. Fragmentation studies both theoretical and experimental will also help to this.

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