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A Comparative study of Interference in photo-detachment of Collinear Tri-atomic Anion and Non-collinear Tri-atomic Anion near Reflecting Surface

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Abstract

Photo-detachment and interferences in the photo-detachment phenomenon are reviewed, focusing on the behavior and characteristic properties of detached electron waves in both systems of collinear and non-collinear arrangements of the atomic centers. The waves that emerged from atomic centers in each of the cases were analyzed after reflection with a hard wall, have been drawn using the theoretical imaging method. After covering some distance, these waves interfere with each other, resulting in a combined wave function in which the electron flux and cross-sectional area have been found in each of the systems. Similarities and differences are found in the same conditions, including the symmetry, the reflecting wall near which the atomic centers are placed, the interference pattern, the probability current density or electron flux, and the cross-sectional area. Finally, the same and different conditions are used to plot the graphs, which clearly show different oscillation patterns for both of them, especially in the case of the energy of the photon and the angle. The results of the review demonstrate that under similar conditions, different negative ions with totally different symmetry and arrangement may have the same or different behaviors. These behaviors are confirmed in light of closed orbit theory, the theoretical imaging method, by revising the analytical expressions and plots.

Keywords: Interference, photo-detachment, Collinear Tri-atomic Anion and Non-collinear Tri-atomic Anion, Reflecting Surface

INTRODUCTION:

Photo-detachment phenomenon has gained quite a fame in the last few decades, mainly due to its applications from atomic level to the cosmological level. Photo-detachment is composed of two words, "photo" means light and "detachment" means to remove, so when light is used to remove electrons from a targeted ion or atomic center then such process is regarded as the photo-detachment. Another important phenomenon is the interference in photo-detachment which is also widely used in molecular physics, plasma physics, molecular dynamics, quantum chemistry, Astor-chemistry and spectroscopy. The interference and the superposition principle give the results for the combined wave function which meet after reflection from the hard wall. In these papers

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photo-detachment phenomenon is used which means when an extra-electron is removed from an anion and it results a change of electron spectrum. This phenomenon is investigated a number of times theoretically as well as experimentally. Time-dependent Schrödinger equation and many computational methods are the tools for the simulation of the dynamics of developing molecular system. Many theories have been applied to achieve suitable results in the different aspects of this phenomenon such as cross beam method, theoretical imaging method, vibrational method, closed orbit theory. These type of studies have been taken under-consideration in static electric field, elastic field, homogeneous electric and magnetic fields, cross gradient electric field, time-dependent oscillating electric field. This phenomenon has solved many aspects regarding the geometry of anion and neutral fragments, electron affinities, the shape of the potential energy surface, rhythmic structure i.e., electron flux, total photo-detachment cross-section, differential cross-section, annular Nano-micro-cavity, curvature of the surface, photo-electron spectrum and absorption coefficient.

Some systems include the anions $H^-, H_2^-, O_2^-, HF^-, O_3^-, N_3^-, H_3^- and\ I_3^-$ etc. Atoms lay non-collinearly in these negative ions whereas some systems are aligned in a linear manner hence called collinear arrangements. These anions have special structures and behaviors, making them research topics in quantum chemistry and molecular physics. In our paper, a comparative study is employed for the concept of quantum interference which is employed to analyses the behavior of detached electron waves in these kind of negative ions.

Background:

This field has been helped in subjects like Astor-chemistry, plasma physics, molecular dynamics, quantum chemistry and spectroscopy.

The photo-detachment phenomenon of hydrogen negative ion gives interesting three center body center due to its strong electron co-relation effects. Analytical expression for the total photo-detachment cross-section of hydrogen negative ion and detached electron flux and observed quantum tunneling effect and oscillation considering electric field Ref [6]. The originating electron waves from hydrogen negative H^- propagate to a large distance in a homogeneous electric field Ref [7]. The photo-detachment cross-section of hydrogen negative H^- agree with quantum approach involving stationary phase approximation and momentum-space wave functions by using closed orbit theory Ref [7] . In static field using closed orbit theory the distance between surface and hydrogen negative ion modulate the photo-detachment cross section and in elastic field perpendicular to electric field detachment spectrum display a staircase structure in contrast with smooth surface Ref [17]. The photo-detachment cross-section increases due to the effect of interference and when two coherent waves originate from a two center system a combine detached electron wave is obtained Ref [16]. Using theoretical imaging method oscillation are induced in the cross-section of hydrogen negative H^- and electron waves differ the value of phase loss for both hard and soft reflecting surfaces and strong interference pattern on the screen are similar to photo-detachment microscopy experiment Ref [14]. In the cross-section of hydrogen negative H^- induced effect of oscillation on screen is observed using closed orbit theory Ref [14]. A detached electron wave function appears when coherent waves superimposed on each other and cross section of three center required photon energy three times to that of one center Ref [16]. The induced oscillation in photo-detachment cross section depends on the separation between the two centers, energy of photon and

direction of the laser beam Ref [13]. Strong energy dependent oscillation appears with the different frequencies of detached electron flux and the cross section of tetra-atomic center is four times to that of one center Ref [18]. The number of peaks increases by increasing the photon energy for a hypothetical linear tetra-atomic center Ref [18]. The radius surface is strongly affected by the cross section as well as the spectra of the flux and oscillation in the spectra is controlled by the curvature of the surface [22]. Severe interference pattern seen in the disconnected electron flux and there is no evidence of oscillation in the cross-section of photo-detachment for hydrogen negative H^- near a hard reflecting surface Ref [22]. When the distance between the di-atomic negative ions is small substantial oscillation appears on the screen whereas for greater value of distance oscillating structure vanishes Ref [22]. For $\theta = 0^\circ$ oscillating structure kept growing while for $\theta_1 = 90^\circ$ they gets shrank incase hydrogen negative H^- Ref [21]. Rough surfaces has significant effect on the electron flux and overall photo-detachment cross-section in case of di-atomic ion H_2^- Ref [22]. Relation surface with free space using low photon energy limits as well as high photo-detachment for hydride ion was discovered Ref [22]. Reflection in the quantum over barrier appears in photo-detachment cross-section and photo-detachment close to potential barrier both on the top and below the barrier play induced oscillation Ref [17]. The results of the photo-detachment cross-section of a negative ion near a repulsive center in a homogeneous electric field agree with the results of Coulomb's Green's function Ref [17]. The oscillatory structures in the electron spectra of hydrogen negative ion in annular Nano-micro-cavity on the sensitivity of cavity based on the computed data Ref [12]. In a particular case non-collinear tri-atomic anion reduces to collinear tri-atomic anion Ref [1]. For the various geometrical energies and detached-electron flux analytical formula was derived using closed orbit theory Ref [16]. Interference cause rhythmic structures between the emitted source waves and returning electron waves along a closed orbit Ref [12]. In an oscillating electric field as compare to static electric field and kinetic energy is not preserved for detached electron wave in hydrogen ion Ref [23]. Reflecting hard wall strongly affects the flux and total photo-detachment cross-section H_3^- is calculated numerically and compared with cross-section of I_3^- Ref [24].

DISCUSSION:

As the core purpose of this paper is to make a comparative study of interferences in photo-detachment of triatomic anions for the collinear and non collinear systems. Many articles have been written and published about interference in photo-detachment which give various results about the various aspects of interference in photo-detachment, a brief discussion regarding there comparison is:

The very first and huge difference is in the arrangement of the atomic centers. In co-linear system the atomic centers are arranged in a linear manner which means all of the atomic centers have common axis of the plane. Whereas in non-collinear arrangement the case is a bit different where two atomic centers are arranged linearly and one lie above the two centers which consequently means that only two atomic centers share a common axis. This can be seen the figure below.

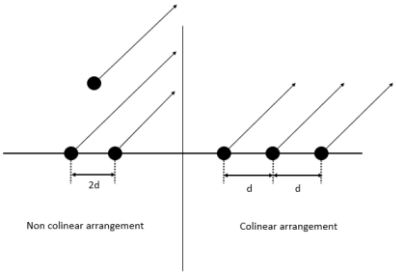

Fig: Arrangement of collinear and non collinear atomic centers is shown.

In the study of interference in photo-detached electron spectra from a non-collinear tri-atomic anion it is shown that when energy of the photon is fixed 30eV and angle is fixed $\eta = 0^{\circ}$ difference between non-collinear tri-atomic anion and collinear tri-atomic anion become undistinguishable which is confirmed both analytically and through simulation which is by plot (a), (b) Ref [1].

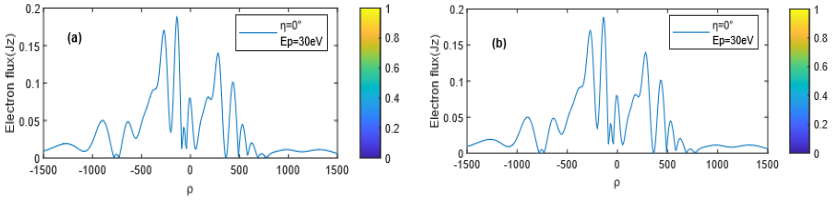

Fig.2 these plots (a) collinear and (b) non-collinear confirming indistinguishing of collinear and non-collinear.

In most of the studies the parameter (η) gives information about the geometry of the anion therefore in the study of non-collinear tri-atomic anion the geometry remains non-collinear when angle is not equal to zero $\eta \neq 0°$ Ref [2]. In the study of a collinear tri-atomic negative anion both the direct and reflected components of the detached electron waves at low photon energy the electron wave have less probability of interference results in smaller distances less probability of interference results in smaller inter-atomic distances and the phase shift does not affect the interference patterns and interference in photo-detachment increases with the increase in the energy of photon Ref [3]. In the study of photo-detachment of hydrogen ion H^{-} in dichromatic oscillating electric fields it is observed that when the electric field is strong enough the detached electron wave returns back to the center from where it was originated Ref [4]. In the study of tri-atomic negative ion is shown that in the analytical expression of the formula approaches one time for one center and two times for two center and three times for three center system and so on Ref [5]. In another study photo-detachment dynamics in a time dependent oscillating electric field the number of closed orbit increases with the increase in frequency of oscillating electric field Ref [6]. In the study of hetero-nuclear di-atomic molecular negative ion the oscillations in the electron flux become much more complicated when the detached electron energy increases Ref [7]. In photo-detachment of H^{-} in a non-uniform electric field a very interesting point is found which is when electric field strength $F = 10kV/cm$, in both uniform and non-uniform electric field the photo-detachment cross-section is in

distinguishable and show similar approach to the photo-detachment cross-section of hydrogen negative ion without any external field graphically smooth curve is obtained for all these phenomenon Ref [8]. In the study of photo-detachment of hydrogen negative ion in homogenous electric and magnetic fields a point to be noted is in parallel uniform electric and magnetic fields when the electric fields strength is increases, the oscillation in the cross-section become much more complicated because as magnetic field strength is fixed the cyclotron period in the motion $\rho - direction$, $t_{ret}^{\circ}=\pi/\omega_2$ is unchanged and the electric field force acting on the detached electron become stronger Ref [9].

CONCLUSION:

In conclusion, we reviewed and compared the interferences in the photo-detachment phenomenon in collinear and non-collinear systems of arrangement. Our main focus was to point out and discuss the differences as well as similarities in their symmetries, interference patterns, flux density, cross section, and every other aspect discussed. We analyzed the interference in the photo-detachment phenomenon and the similarity and differences of the interference phenomenon under the same conditions of energy of the photon (eV) and angle. We came across the result that when the energy of the photon is fixed at 30 eV and the angle is fixed $\eta = 0^{\circ}$, both collinear tri-atomic anion and non-collinear tri-atomic anion show the same interference phenomenon. In most cases, either a homo-atomic anion or a hetero-atomic anion, either direct electron waves or reflected electron waves at low photon energy with a lower probability of interference, have been reported. In most cases of multi-atomic anion, there is less probability of interference because smaller atomic distances and phase shifts do not affect the interference patterns. The detached electron waves return to their original center, especially in the case of mono-atomic anion, when the electric field is strong enough. In most of the cases, the number of closed orbits increases with the increase in oscillating electric field, and terms in analytical expression increase with the increase in the number of centers, but their values depend upon the mode of interference. In the case of mono-atomic anion, when field strength is equal to the photo-detachment cross-section, it is indistinguishable in both uniform and non-uniform electric fields and has a similar approach to the photo-detachment cross-section of mono-atomic anion without any external field. The complexity of the oscillation in cross-section also depends on the cyclotron period.

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