Comment on "Coherent interference in the resonant dissociative electron attachment to carbon monoxide"

Pamir Nag and Dhananjay Nandi*
Indian Institute of Science Education and Research (IISER) Kolkata, Mohanpur 741246, India
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In a recent article [Phys. Rev. A **88**, 012708 (2013)], Tian *et al.* claimed coherent interference among the various negative ion resonant states involved in the dissociative electron attachment (DEA) to carbon monoxide (CO) by investigating O^- angular distribution using the anion velocity time-sliced map imaging technique. However, our recent detailed study [Phys. Chem. Chem. Phys. **17**, 7130 (2015)] on DEA to CO using the identical technique shows that the above claim can be questioned.

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In a recent article [1] the momentum images of O^- ion produced from the dissociative electron attachment (DEA) to carbon monoxide (CO) were presented at three different electron energies, using a modified version of the velocity slice imaging technique [2]. The proposed mechanism based on only one or two set(s) of data described in the article can be questioned. There is a lack of valuable information in the article, e.g., resonance energy, kinetic-energy distribution, momentum images at higher electron energies, etc. Moreover, the authors have not described the two distinct processes after Chantry [3] that were studied quite extensively earlier [4] using precision spectroscopy and the conventional turntable technique. Recently, we studied the complete dynamics using an identical technique and setup as described in Ref. [5] but with minor modifications towards the flight tube length and detector size. In the present setup, both the flight tube length and detector effective diameter is made doubled compared to Ref. [5] in order to improve the mass resolution and to detect higher energy ions, respectively. The two-dimensional detector used in the present study is a microchannel plate (MCP) based delay-line hexanode, unlike the MCP based wedge-and-strip anode used in Ref. [5]. The recent data obtained with this technique [6] provided a more accurate description of the dynamics for the DEA to CO. Using the theoretical model [7] and (within the axial recoil approximation) presumably the DEA process experiences coupling between the states in a straightforward way [8], the authors claimed coherent interference among the different negative ion resonant (NIR) states involved in the process. This effect is very unlikely to occur since the coupling between the states is rotational and at this small energy it would be small [4], if any. We could satisfactorily explain our observations using the same theoretical model [7], with no need to introduce by hand the interference between the different states involved in the process.

The article [1] presented only two angular distribution of O^- data at 10.0 and 10.6 eV with possible fits. At 10.0 eV, the angular distribution data showed backward distribution but no forward distribution. Their best fitted data were almost the same by considering the two-state (Σ and Π symmetry) model with and without interference between the different states. This observation was explained in light of either the destructive interference for the outgoing waves or two states do not couple together. However, their data at 10.6 eV showed a dramatic change in the angular distribution: the vanishing backward distribution and forward-backward asymmetry. In order to obtain a better fit to the data, the authors used three states [removed one (Σ) and introduced two new (Δ and Φ) from the above] and considered interference among the different states involved. This is actually striking to us. Why is the situation so different by changing the primary electron energy that is comparable with the energy resolution of the electron beam used? How is it possible to introduce a new mechanism with only one set of data?

Our measurements using the recently developed momentum imaging technique at similar electron energies and also over the entire energy range around the resonance clearly showed the existence of backward distribution with clear forward-backward asymmetry. Moreover, we observed the two small forward lobes that Tian *et al.* expected for their 10.6-eV data if no interference between the states were involved. For clarity the kinetic-energy distribution is shown in Fig. 1(a); the angular distributions with best fit using the two states (up to four partial waves) theoretical model (under axial recoil approximation) for processes I and II are displayed in Figs. 1(b) and 1(c), respectively, taken at the incident electron energy of 10.5 eV. We clearly identify two different processes observed earlier [4] with distinct kinetic energy and angular distribution. Furthermore, we could explain our observations within the axial recoil approximation and theoretical model [7], with no need to introduce interference between the different NIR states. The observed forward-backward asymmetry is explained due to the interference between the different partial waves involved in the processes as is obvious from the theoretical model [7]. In the following section we discuss the possible sources that might be the reasons for the observed drastic differences.

Although Tian *et al.* used the velocity time-sliced map imaging technique [2] as used by us [5], the two spectrometers and slicing process are quite different from one another. We do not use any wire mesh in the path of the ion trajectory, whereas Tian *et al.* used a wire mesh at the puller electrode and additionally inserted few more electrodes in their spectrometer. The use of wire mesh in the velocity map imaging spectrometer has a serious drawback as clearly demonstrated by Eppink and Parker [9] in the pioneer work and recent review [10]. We also observed a similar effect by implementing a fine wire

*dhananjay@iiserkol.ac.in

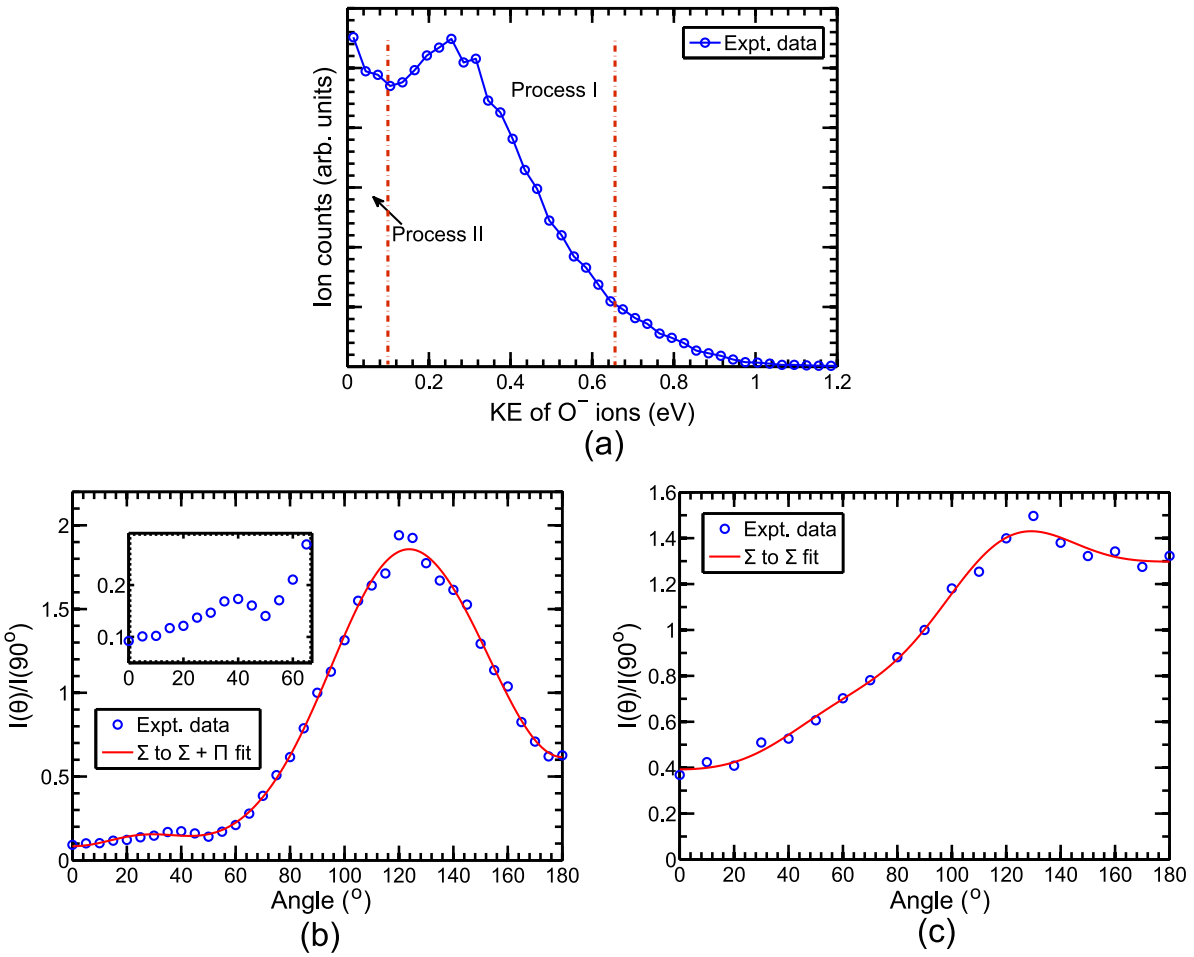

FIG. 1. (Color online) (a) Kinetic-energy distribution of O^- ions arising from DEA to CO at 10.5 eV incident electron energy. The vertical dashed lines in the graph show the regions for processes I and II. The angular distribution (normalized at 90°) at above electron energy with ion kinetic energy in the range (b) 0.10–0.65 eV (Process I), and (c) 0.00–0.10 eV (Process II), respectively. The solid curves in (b) and (c) are angular distribution data fitted with the theoretical model using $\Sigma + \Pi$ and Σ final-state transition, respectively, under axial recoil approximation.

mesh at the puller electrode. For the time slicing, Tian *et al.* pulsed the detector to select the central slice of the "Newton sphere" of negative ions. We do not pulse our detector and introduced a different time slicing in order to select the central slice of the Newton sphere of the detected negative ions. We record the time-of-flight (t) and (x, y) position in the list mode (i.e., recorded event by event) of the detected ions. From the time of flight we can separate out different masses. For a given ion, we apply a small time gate (∼50 ns) and analyze the two-dimensional (time-sliced) images in offline. The central slice corresponds to the time-sliced image with bigger diameter. Thus, the time-slicing technique used by us is less erroneous.

We conclude that the results reported in Ref. [1] are inaccurate and insufficient to propose a new mechanism. In the last section of the article, the authors discussed the differences between their results and those of Ref. [4], but this comparison is not accurate. Our suggestion or comment to the authors is that they should consider not to use any wire mesh in their spectrometer and establish the velocity map imaging technique by comparing the available data within the angular range using the conventional turntable experiment.

[1] S. X. Tian, B. Wu, L. Xia, Y.-F. Wang, H.-K. Li, X.-J. Zeng, Y. Luo, and J. Yang, Phys. Rev. A **88**, 012708 (2013).
[2] B. Wu, L. Xia, H.-K. Li, X.-J. Zeng, and S. X. Tian, Rev. Sci. Instrum. **83**, 013108 (2012).
[3] P. Chantry, Phys. Rev. **172**, 125 (1968).
[4] R. I. Hall, I. Čadež, C. Schermann, and M. Tronc, Phys. Rev. A **15**, 599 (1977).
[5] D. Nandi, V. S. Prabhudesai, E. Krishnakumar, and A. Chatterjee, Rev. Sci. Instrum. **76**, 053107 (2005).
[6] P. Nag and D. Nandi, Phys. Chem. Chem. Phys. **17**, 7130 (2015).
[7] T. F. O'Malley and H. S. Taylor, Phys. Rev. **176**, 207 (1968).
[8] R. D. Levine, *Molecular Reaction Dynamics* (Cambridge University Press, New York, 2005).
[9] A. T. J. B. Eppink and D. H. Parker, Rev. Sci. Instrum. **68**, 3477 (1997).
[10] C. Vallance, Philos. Trans. R. Soc. London A **362**, 2591 (2004).