Comment on "Corrections to vicinage-effect data for molecular ions due to foil inhomogeneities"

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Abstract

An estimation of the influence of the target foil roughness on the molecular vicinage effect in the stopping cross sections has recently been presented [Phys. Rev. A 40, 7369, (1989)], yielding corrections of the same order as the observed effect. We show that the presented values are based on an assumption which is not in accordance with cited experimental data, besides containing errors which led to an overestimation of the roughness influence on up to one order of magnitude in certain cases, thus making meaningless some of the presented conclusions.

It has been observed experimentally that the energy loss of H_2^+ in thin carbon and aluminum foils at low and intermediate projectile energies is not twice the energy loss of protons of the same velocity, indicating the existence of a molecular vicinage-effect [1-4]. This effect is projectile energy dependent.

In a Brief Report by Jakas and Capuj [5] (hereafter referred to as JC) it is stated that foil inhomogeneities produce an effect of similar characteristics, so as to be able to interpret previous molecular energy loss measurements without inclusion of a molecular vicinage effect in the stopping cross section.

The argument is that as the fraction Y of molecules transmitted through a foil is strongly dependent on the foil thickness, therefore when detecting transmitted molecules, one observes a relatively bigger proportion of molecules which traversed thinner foil sections, yielding smaller mean energy losses [2].

JC introduce a projectile velocity dependence of the effect by an assumed energy dependence of the fraction of transmitted molecules, which is in disagreement with molecular yield data, as will be discussed later in this comment.

From the formulas given by JC, and using their notation, following expression results, linking energy loss $\langle \Delta E \rangle$ measurements with the corresponding stopping cross sections S, under inclusion of the foil inhomogeneity effect:

$$\frac{S(H_2^+,\ H_2^+)}{2S(H^+,\ H^+)} \cong \left[1 - \frac{\partial \ln Y(\Delta t, v)}{\partial \ln \Delta t} \rho^2 \right] \frac{\langle\Delta E\rangle(H_2^+,\ H_2^+)}{2\langle\Delta E\rangle(H^+,\ H^+)}$$

Here the first and second arguments of S and $\langle\Delta E\rangle$ are the incoming and outgoing particles respectively, $Y(\Delta t, v)$ is the molecular yield as a function of the foil thickness Δt traversed by the molecules and the projectile velocity v, and ρ being the foil roughness coefficient. The term in brackets approximately reproduces the influence of the foil inhomogeneities.

To get values, JC approximate the yield $Y(\Delta t, v)$ by $\exp(-\gamma\tau)$, γ being a constant and τ being the dwell time of the projectile in the foil, i.e. (following their notation) $\tau = x/v$, where x is the geometrical foil thickness, and citing Refs. [6 - 9] as sources. With this approximation they arrive to the following velocity dependent expression for the correction term:

$$\left[1 - \frac{\partial \ln Y(\Delta t, v)}{\partial \ln \Delta t} \rho^2 \right] \cong 1 + \gamma\langle x\rangle\rho^2/\ v$$

where $\langle x\rangle$ is the mean geometrical thickness of the foil.

We remark here that the approximation $Y(\Delta t, v) \cong \exp(-\gamma\tau) = \exp(-\gamma x/v)$ does not rely on the primary experimental data presented in the references cited by JC. Although in these references the yields are mostly plotted as a function of τ, in this case this parameter is merely a thickness scale, as clearly arises from the fact that measurements performed at different projectile energies are representated as different curves on the same plot, as can be seen for instance in Fig 1 of [9]. Even more, for instance in Fig. 7 of Ref. [6], and Fig. 2 of Ref. [10], the yields Y corresponding to different projectile energies are presented directly as a function of the foil thickness, which is the direct experimental parameter, and there one can see that the data correspondig to different energies are practically superposed, i.e. the slope of Y is practically energy independent, opposed to the $1/v$ slope dependence assumed by JC.

Therefore JC's fundamentation of the by themselves claimed existence of an increased foil inhomogeneity influence at lower energies is not valid.

We evaluate the roughness effect using the data from the Y versus thickness plots taken from Fig 7 of Ref [6] and Fig 2 of Ref. [10]. From there we get $Y = k\exp(-\gamma'\Delta t)$ as fitting the data in the thickness range we are treating here. This leads to the following expression for the corrective factor:

$$\left[1 - \frac{\partial \ln Y(\Delta t, v)}{\partial \ln \Delta t}\, \rho^2 \right] \cong 1 + \gamma' \langle x \rangle \rho^2$$

Here the thickness Δt traversed by the ions has been approximated by the mean geometrical foil thickness $\langle x \rangle$.

The γ'-values from the cited sources are

$\gamma' = -0.36\ [1/(\mu g/cm^2)]$ and $\gamma' = -0.35\ [1/(\mu g/cm^2)]$ respectively, yielding corrective terms $\gamma' \langle x \rangle \rho^2$ of approximately 1% and 2 % correspondig to carbon foils of $\simeq 3\ \mu g/cm^2$ ($\cong$ 300 a.u.) with ρ values of 0.1 and 0.15 respectively. This contrasts with the corresponding corrections presented in Fig. 3 of Ref. [5], which are 9 % and 20 % at the low energy limit (E = 25 keV), and 2 % and 7 % at the high energy limit (E = 260 keV) of the experimental data presented in the figure.

From this we conclude a small incidence of the foil roughness on molecular vicinage effect measurements with parameters like the foregoing, contrarily to what stated by JC. This implies that the corrections presented in Fig. 4 of the commented Report are not realistic either.

Other points from JC which should be remarked are:

a) The first sentence of the last paragraph of page 7370 is not true: The bigger part of the data shown inf Figs. 1 and 2 of Ref. [5] lie inside the region where $v > v_l$ holds.

b) The first two $\langle x \rangle$ values from Table I are erroneous. The first one, corresponding to Al, should be 400 instead of 300, and the second one, corresponding to C, should be 300 instead of 400. According to this, the tabulated v_l values are too interchanged.

c) In Fig. 3 showing key results of their calculations, the presented values can not be reproduced, even using their $Y(\Delta t, v)$ value. The values one gets with the correct $\langle x \rangle$ value for C, are significantly lower than the plotted ones.

Beside this, the curve corresponding to $\rho = 0$, which should reproduce the experimental energy loss ratio data for C, rather fits the combined data of Al and C. This makes no sense because the corrections for Al can not be calculated due to the lack of Y-slope data for this element.

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References:

1) J. C. Eckardt, G. H. Lantschner, N. R. Arista, and R. A. Baragiola, J. Phys. C 11, L851 (1978).

2) Roman Laubert, IEEE Trans. Nucl. Sci. NS-26, 1020 (1979).

3) R. Levi-Setti, K. Lamm, and T. R. Fox, Nucl. Instrum. Methods 194, 281 (1982).

4) M. Steuer, D. S. Gemmell, E. P. Kanter, E. A. Johnson and B. J. Zabransky, Nucl. Instrum. Methods 194, 277 (1982).

5) M. M. Jakas and N. E. Capuj, Phys. Rev. A 40, 7369 (1989).

6) Werner Brandt and R. H. Ritchie, Nucl. Instrum. Methods 132, 43 (1976).

7) J. C. Poizat and J. Remillieux, Phys. Lett. 34A, 53 (1971).

8) N. Cue, N. V. de Castro Faria, M. J. Gaillard, J. C. Poizat, and J. Remmilieux, Nucl. Instrum. Methods 170, 67 (1980).

9) N. Cue, N. V. de Castro Faria, M. J. Gaillard, J. C. Poizat, J. Remmilieux, D. S. Gemmell, and I. Plesser, Phys. Rev. Lett. 45, 613 (1980).

10) M. J. Gaillard, J. C. Poizat, A. Ratkowski, and J. Remillieux, Nucl. Instrum. Methods 132, 69 (1976).