Charge Exchange Cross-Sections for Multiply Charged Ions

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ABSTRACT

A new empirical relation for charge exchange cross-section has been proposed for different charge states of C, N and O colliding with neutral hydrogen. Results are compared with the experimental data.

Charge exchange cross-sections play an important role in doing numerical simulation of impurity transport in Tokamaks. So far only approximate expressions for charge exchange cross-sections have been used in code development work.[1-5] These expressions as is well known show a large deviation from the experimental results for ionic velocities less than v_0 (the Bohr orbital velocity), because in these expressions, there is no dependence on mass and energy of the colliding ions while experimentally, one observes a significant dependence of the cross-sections on these factors.[6] So, in simulation studies, one is either grossly under-estimating or over-estimating the role of charge transfer processes. So it is desirable to develop a theoretical expression for charge transfer cross-section which could reproduce experimental results more accurately. So far, the theoretical work done in this direction has not yielded reasonable results.

So an empirical relation is presented for the charge transfer cross-section which reproduces reasonably well the experimental data for various charge states of C, N and O colliding with neutral hydrogen atom.[7-10]

The proposed empirical relation.

The proposed empirical relation has been defined in two parts: one for energy $E < 0.7$ (KeV/a mu) and other for $E \geq 0.7$ (KeV/a mu). The first part is

$$Q_C^P = \alpha Q_C + (M)^{0.56} q^{\beta} E \qquad \ldots(1)$$

in which

$$\beta = 2.4 \text{ for } q \leq 3 \qquad \ldots(2)$$

$$= 2 \text{ for } q > 3 \qquad \ldots(3)$$

where $\alpha = 0.1$, q, M and E are the charge state, mass and energy (KeV/a mu) of the colliding ions and Q_C is the empirical relation defined as:

$$Q = A q^{\alpha} I^{\beta} \qquad \ldots(4)$$

where $A = (1.43 \pm 0.76) \times 10^{-12}$
$\alpha = 1.17 \pm 0.09$
$\beta = -2.76 \pm 0.019$
$I = 13.6$ eV

The second part is:

$$Q_C^P = \alpha Q_c - (M)^{-0.43} q^{1.17} E \quad ..(5)$$

in which $\alpha = 0.69$

For checking the accuracy of these expressions, one way is to calculate the theoretical cross-sections for different ions separately at different energies and compare these results with the available experimental data. But following the recent trend of uniform scaling, the theoretical values are grouped in two straight lines:

$$y = 1 + x \quad \text{from } E < 0.7 \text{ (KeV/amu)} \quad ..(6)$$

$$= 1 - x \quad \text{from } E \geq 0.7 \text{ (keV/amu)} \quad ..(7)$$

where $Y = Q_C^P / \alpha Q_c$

$x = (M)^{0.56} q^{\beta} E / \alpha Q_c$ and $\frac{(M)^{-0.43} q^{1.17} E}{\alpha Q_c}$ in eqs. (6) & (7)

Of course in Eq.(6) account has to be taken for $q \leq 3$ or $q > 3$. These lines are shown in Figs. 1,2,3. The experimental values for different ions with different q values are shown by (x) in these figures. We have also plotted the values given by the emperical relation(4) which are shown by thick lines in these figures.

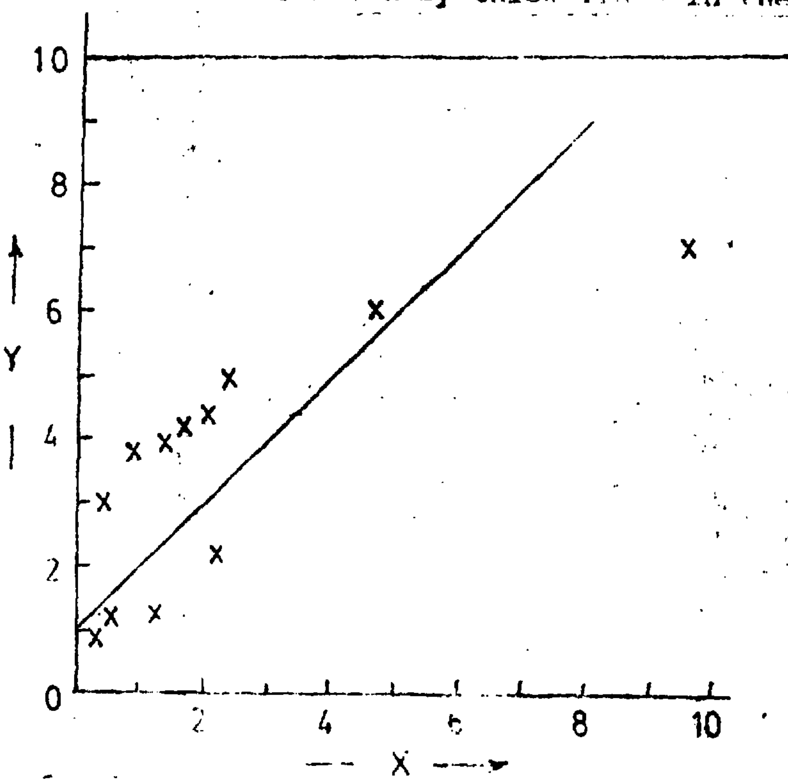
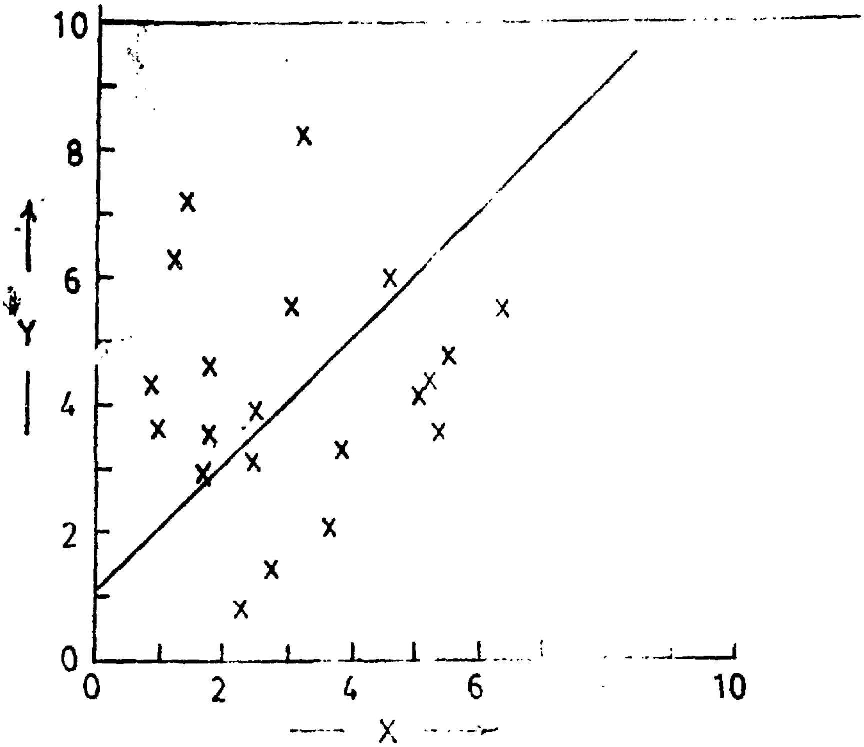
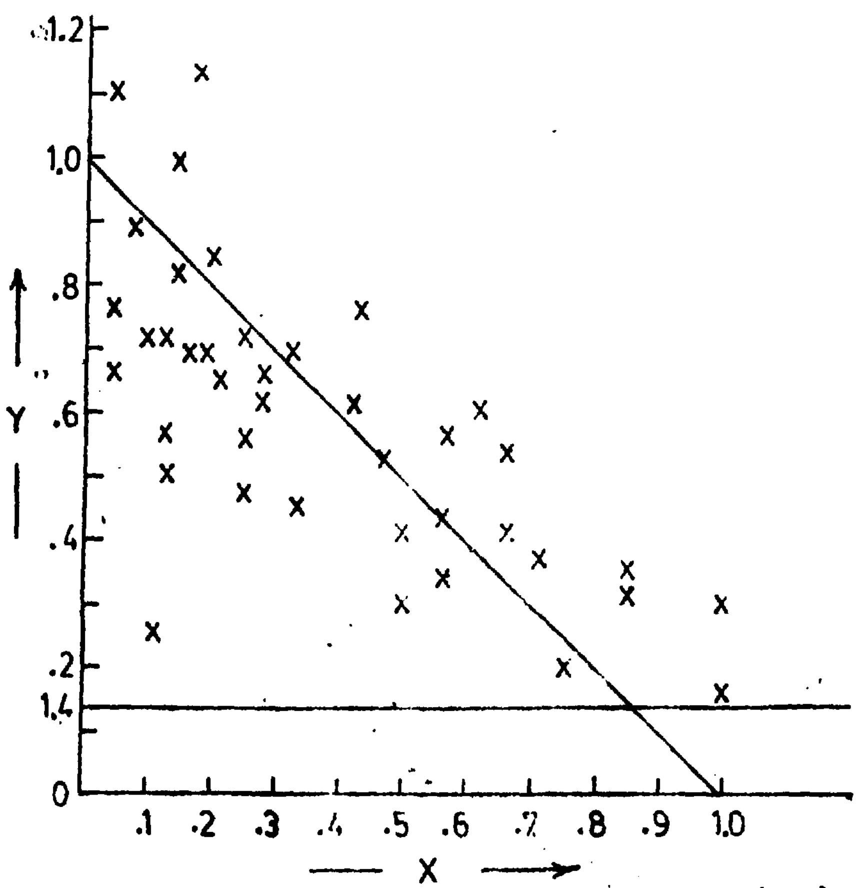


FIG.1 Values of X and Y for $E < 0.7$ (KeV/amu) and $q \leq 3$



Values of X and Y for E ≥ 0.7 (KeV/amu)

FIG, 2 and $q > 3$



Values of X and Y for $E \geq 0.7$ (KeV/amu)

FIG. 3

As is clear from these figures, the emperical relation (4) grossly under-estimate or over-estimate the values. The present relation shows an agreement within the reasonable limits. In some cases, it is within the experimental errors.(the experimental errors are fairly large in the low energy region).

Finally, one would like to compare the present relation with the data for other elements but apparently not much data is available.

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