Non-Equilibrium in Ionized Gases Determined by Charged Particle Collisions with Molecules

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In their recent, excellent, review Taccogna and DiLecce [1] have tried to systematize the types and to some degree the origins of non-equilibrium in low temperature plasmas. Above all, that paper made a point (perhaps not intentionally) that the intellectual underpinning of the non-equilibrium physics is in explaining how all these different manifestations come about and how those may be explained. We have been trying to make a similar point for many years in a number of review lectures and even some of the papers albeit indirectly in attempts to show how swarm physics brings non-equilibrium into the plasma models [2-5]. The basic idea was that, while thermal equilibrium (TE) is able to provide us with laws that are universally applicable the model of thermal equilibrium is hardly ever applicable in its true and full meaning. At the same time non-equilibrium plasmas with their diversity cannot be explained in terms of formulae but their fundamental description is based on three pillars:
1) elementary data (for a variety of existing particles including the data for their reactions);
2) procedures to model (equations, transport equations, continuity etc…) and
3) inclusion of the boundaries.
In that respect the common, universal rules are provided in the realm of experience rather than the universal, prescribed thruths (formulae). Please note that Local Thermodynamic equilibrioum (LTE) is just the simplest model of non-equilibrium. The main systematics should include splitting phenomena observed in the ionized gases (which also includes positrons in gas filled traps and in the local atmosphere) into two groups:
a) Local field equilibrium (when properties may be stable in space and/or time but processes are not balanced as expected for TE).
b) Non-local, non-hydrodynamic phenomena.
Under the latter group one may label different situation when balances of one or more of the main conserved quantities are not met (number due to non-conservative collisions or local losses, energy and momentum). The relaxation time for these processes may be determined from the elementary processes and the available data and were used as the basis for correcting for non-local phenomena in fluid models. Different combinations of non-equilibrium in different situations produce a large number of the so called 'kinetic phenomena' that may not be easily explained based on the elementary data and where one needs kinetic modelling to reproduce the phenomenon.

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