Transport properties for planetary atmospheres: the hybrid approach

Annarita Laricchiuta[1][0000−0002−6752−7419], Antonio D'Angola[2,1][0000−0002−7900−9731], and Gianpiero Colonna[1][0000−0002−4993−4838]

[1] CNR ISTP Bari Section (Italy)
[2] Università della Basilicata Potenza (Italy)
annarita.laricchiuta@cnr.it

Abstract. The need of complete datasets of collision integrals for the accurate estimation of transport properties of plasmas generated during the entry phase in planetary atmospheres and the strategies adopted in the construction of the core database of the tool EquilTheTA are discussed and reviewed.

Keywords: transport properties · collision integrals · phenomenological approach.

The modeling of hypersonic entry of bodies in the Earth atmosphere needs the characterization of the thermodynamics and transport properties of the plasma formed in the shock layer, including the contamination of chemical species ablated from the surface. Silicon compound contamination is relevant either to the ablation of ceramic tiles of TPS or to the evaporation of chondrites (stony-meteorites).

The calculation of chemical equilibrium, thermodynamics and transport is performed with the web-access tool EquilTheTA (EQUILibrium for plasma THErmodynamics and Transport Applications) [1] designed and implemented in the framework of the cooperation between the CNR ISTP Bari and University of Basilicata. The tool, accurate, stable and reliable in wide temperature and pressure ranges, derives the quantities from core databases of atomic and molecular energy levels and collision integrals, in the frame of the classical theory of statistical thermodynamics and the Chapman-Enskog theory, respectively.

The creation of a complete database of transport cross sections for binary heavy-particle interactions in complex mixtures including large number of species has been successfully tackled adopting a hybrid approach that combines the traditional *multi-potential* with the *phenomenological* approach [2, 3]. In the multi-potential approach the effective collision integrals for a given interaction results from the averaging procedure of terms corresponding to each allowed interaction between the two colliding partners, while the phenomenological approach is very attractive, allowing the derivation of complete and consistent datasets of collision integrals for possibly any interaction, estimating the interaction potential on a physically sound basis. In fact, the average interaction is modeled by

an Improved Lennard Jones (ILJ) potential whose features (depth and position of the well) are derived by correlation formulas given in terms of fundamental physical properties of interacting partners (dipole polarizability, charge, number of electrons effective in polarization). These approaches combined with the asymptotic approach for the estimation of the resonant charge-exchange contribution to odd-order collision integrals, represent a powerful strategy to extend the collision integral database.

The transport properties of air plasmas in presence of silicon species, originated from ablation of SiO_2 and SiC, have been investigated [4, 5].

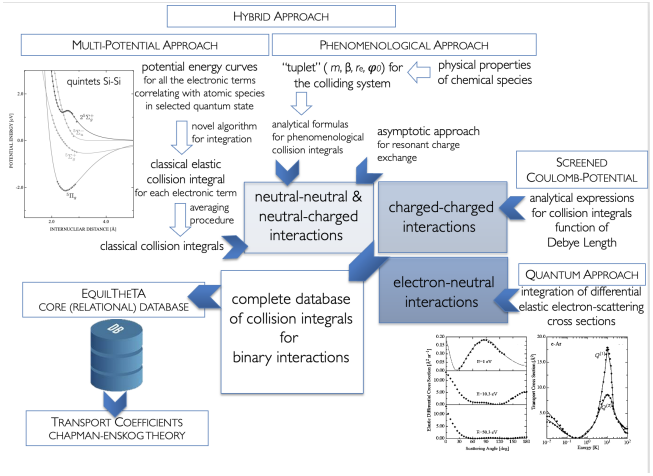

Fig. 1. Sketch of the approach in the creation of the core database of EquilTheTA.

References

1. 2022 EquilTheTA http://phys4entrydb.istp.cnr.it/EquilTHETA/
2. Capitelli, M., Cappelletti, D., Colonna, G., Gorse, C., Laricchiuta, A., Liuti, G., Longo, S., Pirani, F.: On the possibility of using model potentials for collision integral calculations of interest for planetary atmospheres. Chemical Physics **338**(1), 62–68 (2007)
3. Laricchiuta, A., Colonna, G., Bruno, D., Celiberto, R., Gorse, C., Pirani, F., Capitelli, M.: Classical transport collision integrals for a Lennard-Jones like phenomenological model potential. Chemical Physics Letters **445**(4), 133–139 (2007)
4. Laricchiuta, A., D'Angola, A., Pirani, F., Pietanza, L.D., Capitelli, M., Colonna, G.: Thermodynamic and transport properties of reacting air including ablated species. In: Hypersonic Meteoroid Entry Physics. IOP Publishing (2019)
5. Colonna, G., D'Angola, A., Pietanza, L.D., Capitelli, M., Pirani, F., Stevanato, E., Laricchiuta, A.: Thermodynamic and transport properties of plasmas including silicon-based compounds. Plasma Sources Science and Technology **27**(1), 015007 (2018)