Sensitivity analysis and uncertainty quantification for electric field determination in air from FNS and SPS intensity ratio

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Frequently used method for the determination of electric field in air discharges is based on the measurement of the ratio of luminous intensities emitted by radiative states of $\mathrm{N_2(C^3\Pi_u)}$ (second positive system) and $\mathrm{N_2^+(B^2\Sigma_u)}$ (first negative system)[1, 2, 3]. This method is used for wide range of pressures from sea level pressures, where it is applied for example to investigation of dielectric barrier discharge, down to very low pressures at ionospheric altitudes for remote sensing of Transient Luminous Events, e.g., lightnings, sprites and blue jets. It is well known that quenching rates of $\mathrm{N_2(C^3\Pi_u)}$ and $\mathrm{N_2^+(B^2\Sigma_u)}$ determined by various experimental methods exhibit serious discrepancies. Therefore we aim to investigate the impact of uncertainties in values of these rates on electric field determined from FNS/SPS intensity ratio.

1. Problem description

In order to investigate densities of chemical species in air, we have implemented plasma chemistry model, which contains 617 processes for $\mathrm{N_2{:}O_2}$ (80%:20%) mixture. Time evolution for plasma chemistry is solved in 0D for an electric field that represents passage of an ionization wave at a given point. We present uncertainty quantification and sensitivity analysis for the kinetic scheme for resulting intensity ratio of the FNS and the SPS. This analysis is based on the Elementary Effects (EEs) method invented by Morris [4]. The EEs reveal the most important reactions [5] at particular pressure conditions. As an example, the most important processes for FNS/SPS intensity ratio at sea level pressure are shown in table 1, figure 1 shows sensitivity plot for these conditions. Uncertainty quantification based on Monte Carlo methods will be applied to investigate the impact of uncertainties in values of rate coefficients and quenching rates on electric field determination from FNS/SPS intensity ratio.

Table 1: The key reactions for the ratio FNS/ SPS.

no.	reaction
10	$\mathrm{e + N_2 \longrightarrow N_2(C^3\Pi_u) + e}$
28	$\mathrm{e + N_2 \longrightarrow N_2^+(B^2\Sigma_u) + 2e}$
331	$\mathrm{N_2^+(B^2\Sigma_u) + N_2 \longrightarrow N_2^+ + N_2}$
23	$\mathrm{e + N_2 \longrightarrow N_2^+ + 2e}$
25	$\mathrm{e + O_2 \longrightarrow O_2^+ + 2e}$
332	$\mathrm{N_2^+(B^2\Sigma_u) + O_2 \longrightarrow N_2^+ + O + O(1S)}$
366	$\mathrm{N_2^+(B^2\Sigma_u) + N_2 + O_2 \longrightarrow N_4^+ + O_2}$
130	$\mathrm{N_2(C^3\Pi_u) + O_2 \longrightarrow N_2 + O + O(1S)}$
50	$\mathrm{e + N_2^+ \longrightarrow N_2^+(B^2\Sigma_u) + e}$

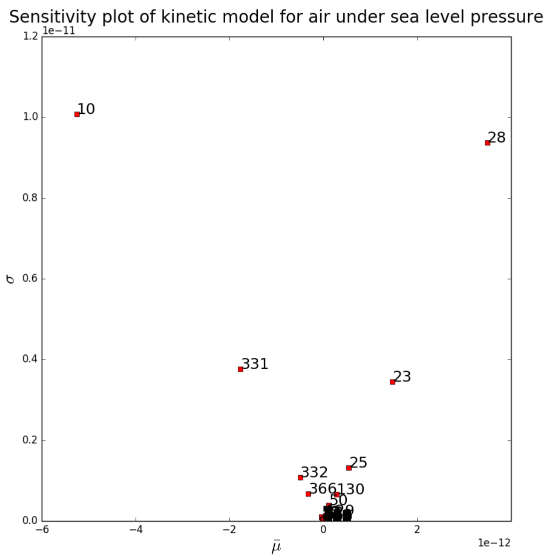

Figure 1: EEs for FNS and SPS ratio.

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3. References

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