Kinetic processes in air mixture $N_2(i)/O_2(i)/NO(i)/N/O$

- Exchange reactions, dissociation and recombination:

$$N_2(i)+O \rightleftarrows NO(i')+N, \quad N_2(i)+M \rightleftarrows N+N+M, \quad NO(i)+M \rightleftarrows N+O+M,$$
$$O_2(i)+N \rightleftarrows NO(i')+O, \quad O_2(i)+M \rightleftarrows O+O+M, \quad (M = N_2, O_2, NO, N, O),$$

- $TV(VT)$ exchanges between vibrational and translational energies:

$$N_2(i)+M \rightleftarrows N_2(i')+M, \quad O_2(i)+M \rightleftarrows O_2(i')+M, \quad NO(i)+M \rightleftarrows NO(i')+M,$$

- VV and VV' vibrational energy exchanges at the collisions of molecules of the same and various species:

$$N_2(i)+N_2(m) \rightleftarrows N_2(i')+N_2(m'), \qquad N_2(i)+O_2(m) \rightleftarrows N_2(i')+O_2(m'),$$
$$O_2(i)+O_2(m) \rightleftarrows O_2(i')+O_2(m'), \qquad N_2(i)+NO(m) \rightleftarrows N_2(i')+NO(m'),$$
$$NO(i)+NO(m) \rightleftarrows NO(i')+NO(m'), \qquad O_2(i)+NO(m) \rightleftarrows O_2(i')+NO(m').$$

Production terms in kinetic equations

- **Exchange reactions:**

$$R^{2\leftrightarrow 2}_{\mathrm{N}_2 i} = \sum_{i'=0}^{l_{\mathrm{NO}}} (n_{\mathrm{NO}i'} n_{\mathrm{N}} k^{\mathrm{N,O}}_{\mathrm{NO}i',\mathrm{N}_2 i} - n_{\mathrm{N}_2 i} n_{\mathrm{O}} k^{\mathrm{O,N}}_{\mathrm{N}_2 i,\mathrm{NO}i'}),$$

$$R^{2\leftrightarrow 2}_{\mathrm{O}_2 i} = \sum_{i'=0}^{l_{\mathrm{NO}}} (n_{\mathrm{NO}i'} n_{\mathrm{O}} k^{\mathrm{O,N}}_{\mathrm{NO}i',\mathrm{O}_2 i} - n_{\mathrm{O}_2 i} n_{\mathrm{N}} k^{\mathrm{N,O}}_{\mathrm{O}_2 i,\mathrm{NO}i'}),$$

$$R^{2\leftrightarrow 2}_{\mathrm{NO}i} = \sum_{i'=0}^{l_{\mathrm{N}_2}} (n_{\mathrm{N}_2 i'} n_{\mathrm{O}} k^{\mathrm{O,N}}_{\mathrm{N}_2 i',\mathrm{NO}i} - n_{\mathrm{NO}i} n_{\mathrm{N}} k^{\mathrm{N,O}}_{\mathrm{NO}i,\mathrm{N}_2 i'}) + \sum_{i'=0}^{l_{\mathrm{O}_2}} (n_{\mathrm{O}_2 i'} n_{\mathrm{N}} k^{\mathrm{N,O}}_{\mathrm{O}_2 i',\mathrm{NO}i} - n_{\mathrm{NO}i} n_{\mathrm{O}} k^{\mathrm{O,N}}_{\mathrm{NO}i,\mathrm{O}_2 i'}).$$

- **Dissociation and recombination:**

$$R^{2\leftrightarrow 3}_{\mathrm{N}_2 i} = \sum_{\mathrm{M}} n_{\mathrm{M}} (n^2_{\mathrm{N}} k^{\mathrm{M}}_{rec,\mathrm{N}_2 i} - n_{\mathrm{N}_2 i} k^{\mathrm{M}}_{\mathrm{N}_2 i,diss}),$$

$$R^{2\leftrightarrow 3}_{\mathrm{O}_2 i} = \sum_{\mathrm{M}} n_{\mathrm{M}} (n^2_{\mathrm{O}} k^{\mathrm{M}}_{rec,\mathrm{O}_2 i} - n_{\mathrm{O}_2 i} k^{\mathrm{M}}_{\mathrm{O}_2 i,diss}),$$

$$R^{2\leftrightarrow 3}_{\mathrm{NO}i} = \sum_{\mathrm{M}} n_{\mathrm{M}} (n_{\mathrm{N}} n_{\mathrm{O}} k^{\mathrm{M}}_{rec,\mathrm{NO}i} - n_{\mathrm{NO}i} k^{\mathrm{M}}_{\mathrm{NO}i,diss}), \quad \mathrm{M} = \mathrm{N}_2, \mathrm{O}_2, \mathrm{NO}, \mathrm{N}, \mathrm{O}.$$

Production terms in kinetic equations

- **Energy exchanges:** $R_{ci}^{vibr} = R_{ci}^{VV} + R_{ci}^{VV'} + R_{ci}^{VT}$ **:**

$$R_{ci}^{VV} = \sum_{mi'm'} \left(n_{ci'} n_{cm'} k_{c,i'\to i}^{c,m'\to m} - n_{ci} n_{cm} k_{c,i\to i'}^{c,m\to m'} \right), \quad c = \mathrm{N_2}, \mathrm{O_2}, \mathrm{NO},$$

$$R_{ci}^{VV'} = \sum_{d} \sum_{mi'm'} \left(n_{ci'} n_{dm'} k_{c,i'\to i}^{d,m'\to m} - n_{ci} n_{dm} k_{c,i\to i'}^{d,m\to m'} \right), \; d = \mathrm{N_2}, \mathrm{O_2}, \mathrm{NO}, \; d \neq c,$$

$$R_{ci}^{VT} = \sum_{\mathrm{M}} \sum_{i'} n_{\mathrm{M}} \left(n_{ci'} k_{c,i'\to i}^{\mathrm{M}} - n_{ci} k_{c,i\to i'}^{\mathrm{M}} \right), \quad \mathrm{M} = \mathrm{N_2}, \mathrm{O_2}, \mathrm{NO}, \mathrm{N}, \mathrm{O}.$$

- **Right parts in equations for atoms number densities:**

$$R_{\mathrm{N}}^{2\leftrightarrow 2} = -\sum_{i=0}^{l_{\mathrm{N_2}}} R_{\mathrm{N_2}i}^{2\leftrightarrow 2} + \sum_{i=0}^{l_{\mathrm{O_2}}} R_{\mathrm{O_2}i}^{2\leftrightarrow 2}, \qquad R_{\mathrm{N}}^{2\leftrightarrow 3} = -2\sum_{i=0}^{l_{\mathrm{N_2}}} R_{\mathrm{N_2}i}^{2\leftrightarrow 3} - \sum_{i=0}^{l_{\mathrm{NO}}} R_{\mathrm{NO}i}^{2\leftrightarrow 3},$$

$$R_{\mathrm{O}}^{2\leftrightarrow 2} = -\sum_{i=0}^{l_{\mathrm{O_2}}} R_{\mathrm{O_2}i}^{2\leftrightarrow 2} + \sum_{i=0}^{l_{\mathrm{N_2}}} R_{\mathrm{N_2}i}^{2\leftrightarrow 2}, \qquad R_{\mathrm{O}}^{2\leftrightarrow 3} = -2\sum_{i=0}^{l_{\mathrm{O_2}}} R_{\mathrm{O_2}i}^{2\leftrightarrow 3} - \sum_{i=0}^{l_{\mathrm{NO}}} R_{\mathrm{NO}i}^{2\leftrightarrow 3}.$$