Kinetic Nucleation in Thermal Non-Equilibrium

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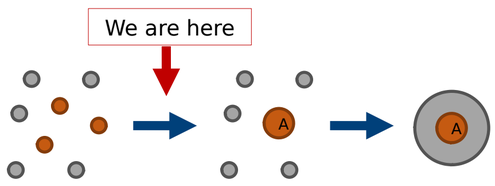
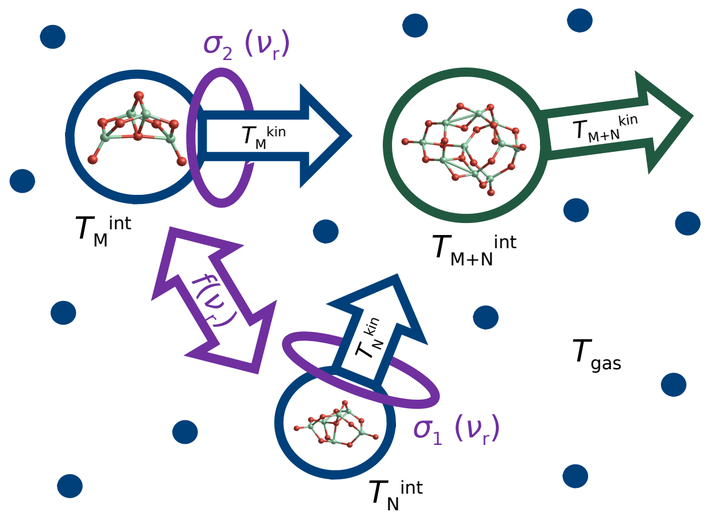
Take home If thermal non-equilibrium is present, kinetic nucleation is affected by it. Nonetheless, the assumption of thermal equilibrium is generally justified for exoplanet atmospheres.

Connection to Exoplanets

Clouds form when materials (●) condense onto aerosols (A). In gaseous exoplanets, aerosols must form from the gas phase (●) via kinetic nucleation. With this work we look at the effect of thermal non-equilibrium.



Kinetic Nucleation

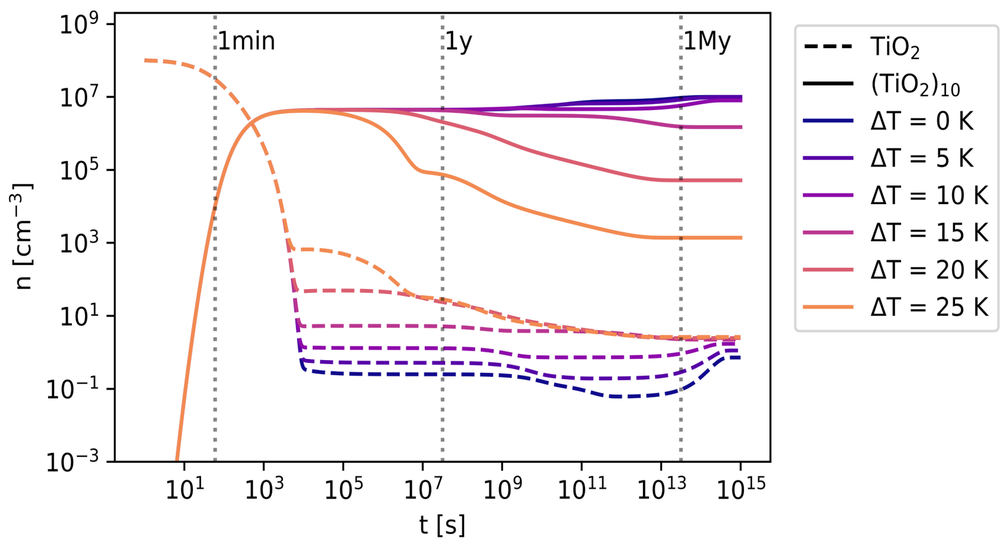


Growth reaction rate k^+:

- T^{int} internal temperature
- T^{kin} kinetic temperature
- T_{gas} gas temperature
- N, M, $N+M$ cluster sizes
- v_r relative velocity between colliding particles
- $\sigma_j(v_r)$ reaction cross section
- $f(v_r)$ velocity distribution

$$k_j^+ = \int_0^\infty \sigma_j(v_r)\, v_r\, f(v_r)\, dv_r$$

Results



Kinetic thermal non-equilibrium

$T_{gas} = T_n^{int} \neq T_N^{kin}$

Internal thermal non-equilibrium

$T_{gas} = T_n^{kin} \neq T_N^{int}$

Assumptions for this example:

- TiO_2 nucleation in a H_2 gas at T_{gas} = 1000 K
- Initial number density $n_{TiO_2} = 10^8$ cm^{-3}
- Kinetic thermal non-equilibrium $T_N = T_N^{kin} = T_N^{int}$
- Temperature offset $\Delta T = T_{(TiO_2)_{10}} - T_{TiO_2}$

Conclusions

- Thermal non-equilibrium can enhance or reduce $(TiO_2)_{10}$ formation.
- Kinetic nucleation in hot, low-density environments (e.g. AGB stars [5]) can be affected by thermal non-equilibrium.
- Thermal equilibrium is a good assumption for exoplanet atmospheres.

Get in Touch!

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References

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Background: tirachard via freepick

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