

We thank the referee for reviewing of our manuscript. Our responses are in blue.

General remarks: This is a well written paper that extends the model for kinetic gas-particle partitioning to include particle-phase diffusion and chemical reaction. The paper also provides evaluation of the theoretical framework of this model with implementation in MOSAIC and comparison of results to a finite-difference solution. Further, growth dynamics of the Aitken and accumulation mode particles are studied at several combinations species volatility, particle-phase diffusivity and particle-phase reaction rate constant. Although the model is immensely complex, and requires number of parameters that are very hard to derive from experiments, the model evaluation advances scientific understanding of kinetic partitioning of SOA and can act as a template to design future SOA formation algorithms for implementation in 3-D Eulerian models. I recommend publishing the manuscript in ACP only after taking into account the following minor changes/additions

Specific comments:

1. One of the major drawbacks of the model is the failure to account for SOA formed through aqueous-phase pathways (Carlton et al, Atmos. Chem. Phys., 13, 10203-10214, 2013). This can be particularly important in areas such as Eastern US and other urban centers where sulfate-rich conditions increase the particle-phase liquid water and subsequently aqueous-phase SOA. This should be highlighted as one of the limitations of the current proposed framework for inclusion in 3-D Eulerian models.

Thanks for mentioning this issue. MOSAIC already performs kinetic partitioning of inorganic gases (H_2SO_4 , HNO_3 , HCl , and NH_3) to size-distributed particles and predicts liquid water associated with inorganic species as a function of relative humidity. While the focus of the present work is on kinetic partitioning of organic gases to particulate organic phase, the new framework can be readily adapted to kinetically partition water soluble organic gases into the particulate aqueous phase if that is the only liquid phase in the particle. However, additional research is needed to extend the present framework to mixed inorganic-organic particles that experience liquid-liquid phase separation (i.e., coexistence of both aqueous and organic phases). We have now cited Carlton and Turpin (2013) and have added this point in the last paragraph of Sect. 3.1.2 and clarified it in the Summary and Implications section.

2. Although the paper focuses on the interplay between organic solute volatility, particle-phase diffusivity and particle-phase reactivity, some discussion on previous studies using accommodation coefficients to impose kinetic constraints on SOA formation arising from mass-transfer during phase transition would be helpful to set up a broader context of the current formulation (Bowman et al., Atmospheric Environment 31, 3921-3931; Saathoff et al., Atmos. Chem. Phys., 9, 1551–1577, 2009; Parikh et al., Atmospheric Environment 45 (5), 1126-1137).

Thanks for pointing this out. We have added the following text in section 3.1 to set up the broader context of the present work: “Previously, the interfacial mass accommodation coefficient (α) has been often used as a tunable parameter to fit the observed kinetic limitation to mass-transfer during SOA partitioning (Bowman et al., 1997; Saathoff et al., 2009; Parikh et al., 2011). However, α does not correctly capture the mass transfer limitations due to particle-phase diffusion and chemical reaction occurring within the bulk of the particle. In the present framework, the interfacial and bulk particle phase mass transfer limitations are represented separately, with the appropriate dependence for the latter on particle size.”

3. A major limitation of this model is the requirement of size-dependent diffusion parameters and kinetic rate constants for actual particle-phase chemical reactions (the specification of such reactions is

still incomplete). Also several combinations of species volatility, particle-phase diffusivity and particle-phase reaction rate constant can lead to the similar aerosol size distributions, making it difficult to verify the parameters experimentally – particularly requiring size distributions of isolated SOA chemical species that are formed as products of particle-phase reactions. The burden of acquiring parameters for the model for it to be implemented in larger-scale models is very high – this caveat should be stressed and the focus of the summary and implications section should be on key scientific findings from the model, rather than suggesting it can be implemented in larger-scale models.

Our view is that there is growing experimental evidence of the effects of particle phase state and particle-phase reactions on SOA partitioning dynamics. The model framework presented here facilitates the representation of these effects in a computationally efficient manner, which can be eventually implemented in large scale models. This is the strength of the new framework rather than the present model's limitation. We have devoted only one sentence to highlight this important feature of the model in the Summary and Implications section, and have left it unchanged. The rest of the material in this section already focuses on summary of the key scientific findings from the present model analysis. We do agree that determining all the relevant phase state parameters and kinetic rate constants important for SOA formation (from different precursors and under different conditions) is a major effort, and expect a community-wide collaborative effort to address the set of new scientific and technical needs of the next generation SOA models. We have revised summary point (e) in the text to emphasize this need.