

The authors present a new flow reactor designed for investigating multiphase chemistry in aerosols and cloud droplets. This is an interesting and technically challenging idea, which could potentially be an important tool to gain insights into these understudied processes. Care was taken in the design of the reactor to avoid temperature gradients due to the UV lamps, which would interfere with multiphase partitioning, to minimize losses of soluble gases, and to strictly control RH. They use a Spot sampler to generate cloud-like droplets from seed aerosol for study in the reactor. They present preliminary results for studies of the influence of aqueous processing on SOA formation in the lab and using ambient air. I believe the manuscript is publishable in AMT after some minor issues are addressed and the manuscript is revised accordingly.

- The article is too long, with 17 figures in the main text. Surely this can be tightened up, with some material moved to SI. At the same time the most interesting figure (the second Figure S2 - there are two Figure S2s) has been relegated to the SI.

We moved Figures 4, 10, and 16 to the supplement. That still leaves 14 figures, which we recognize is high, but we feel that all of those that remain are important for accompanying the text.

- The abstract is also too long. It's not immediately clear what "transmission efficiencies" are upon reading the abstract without first reading the manuscript.

We addressed both of these issues by deleting the following from the abstract: "The transmission efficiency of O₃ and CO₂ for all RH and of SO₂ for low RH exceeds 90 %, while it falls to about 70 % for SO₂ at 100 % RH. Particle transmission efficiency increases with increasing particle diameter from 0.67 for 0.050 μm particles to 0.98 at 0.20 μm, while that of the ~3.3 μm droplets formed on seed particles is greater than 80 %."

- Why is K₂SO₄ used instead of other particle types which may be more representative of atmospheric aerosol or more typical of laboratory studies of aerosol and cloud chemistry? I think the question is answered several pages later on line 496 but should also be acknowledged when this is first mentioned. Also note that "neutral" isn't really representative of ambient aerosol or cloudwater pH (cf. Pye et al. 2020)

It may be that the reviewer didn't notice the description accompanying the initial mention of K₂SO₄ starting on Line 210: "To date, most experiments have used potassium sulfate (K₂SO₄) seed particles because they are non-acidic, have a dynamic shape factor close to 1, and effloresce at an RH of about 60 % (Freney et al., 2009), which permits measurements without ALW at higher RH than would be possible with common aerosol types such as ammonium sulfate and sodium chloride."

- the size dependence of the particle transmission efficiency is mentioned, and compared with other studies, but no physical explanation for decreasing transmission for smaller particles is given. One would expect the opposite.

The original sentence: “The particle transmission efficiency increases with increasing particle size, from 0.67 for 0.050 μm particles, to 0.94 at 0.080 μm , and 0.98 at 0.20 μm .” was extended to (briefly) explain the size dependence: “As expected for the particle size range considered for which the dominant loss mechanisms are Brownian motion and electrostatic attraction to charged surfaces, the particle transmission efficiency increases with increasing particle size, from 0.67 for 0.050 μm particles, to 0.94 at 0.080 μm , and 0.98 at 0.20 μm .”

- The SO₂ transmission efficiency at high RH is low. Presumably studying SO₂ multiphase chemistry was one of the main intended purposes of this apparatus. Can the authors comment on how this issue may impact the design of future studies?

The experiments described in the manuscript in which SO₂ was injected and conversion to sulfate aerosol measured were meant to test the reactor with an extensively studied chemical system. The primary utility of the APPA is not for studying reaction of soluble gases that are directly injected, but rather further reaction of soluble products of gas phase oxidation of injected insoluble gases. Wall losses of those soluble products are expected to be lower simply because they will encounter a cloud of droplets in their path between where they form and the wall.

- line 444: 'described in by (Mitroo et al)'... clean that up

Now “described in Mitroo et al. (2018).”

- residence time distribution: why is there a distribution at all if the gases or particles are introduced in the same location and sampled in the same location (if this is not the case it's not possible to tell from the text)? How are three measurements sufficient to construct the whole RTD curve and detect the absence of a long tail?

Some smearing of an input pulse of particles or gases is unavoidable because the laminar velocity profile through the reactor is parabolic and not flat. The RTD tests are intended primarily to evaluate the contribution of things like mixing at the entrance and exit. The particle and gas measurements made at the outlet of the reactor were continuous and high time resolution, spanning the time between injection and several minutes later when concentrations had decreased to ~ 0 . The “three” measurements were simply repeated tests of the same thing to ensure that the results were repeatable.

- line 490 - I would either delete or rephrase this. You are presumably introducing this apparatus for the first time in this manuscript, why are you making this statement about it not being applied very often to cloud chemistry studies when that is the most novel and unique application?

The sentence in question is “Though, like most OFRs, the APPA reactor is most often used to measure aerosol formation resulting from OH chemistry, conditions inside the reactor during cloud chemistry 490 experiments were first evaluated through the well-studied oxidation of dissolved SO₂ by O₃, leading to formation of sulfuric acid and growth of the particles on which the droplets formed.”

The intent of the sentence is not to suggest that the reactor will not often be used to study cloud chemistry, but rather that it will not often be used to study aqueous phase oxidation by ozone and not hydroxyl radical.

- Figure 9 and Figure S2. See my comment above about the second Figure S2. It is much more interesting than Figure 9. Figure 9 has been sufficiently described in the text lines 500-507. It could be made panel B of a figure which focuses on the data in Figure S2, moved to SI, or eliminated. How was the low SO₂ transmission efficiency dealt with in these calculations?

We wanted to include one figure that shows the change in particle size distribution resulting from addition of secondary aerosol. We felt that original Figure 14 (Figure 12 in revision) was a better choice because it shows the result of the type of experiment the APPA is primarily designed for. As noted above, the SO₂ to SO₄ conversion experiment was meant to test the reactor with a well-studied chemical system and, thus, it seems more important to include results that can help readers visually evaluate how similar the experimental results are to expectations. The figure in the supplement shows how the size distribution is altered, but does not allow a reader to evaluate the meaning of the extent of change.

The SO₂ concentration used in the calculations was determined based on a known concentration in gas mixture and a measured flow rate. No correction for wall loss was included. Though it may seem that this would result in a significant low bias based on original Figure 6, those transmission efficiency tests were done without introduced droplets. Thus, much of the SO₂ lost during the transmission efficiency tests will instead dissolve and react in the droplets.

- Is the relatively short residence time of APPA compared to a chamber experiment an issue when it comes to SOA studies?

Absolutely, but this is an issue that affects all OFRs and is discussed at length in other publications. Adding a discussion here would add even more to an already long manuscript.

- What is the reader supposed to take away from the SOA yield studies shown in Figure 15? Were these yields consistent with expectations?

The primary reason for including the discussion and figure was to show the clear influence of liquid water on the amount of secondary aerosol formed.

The following was added to provide some context for the measured yields: "The yield measured with no liquid water present is similar to the 0.18 – 0.28 range reported by Nakao et al. (2011), though the comparison is indirect because of differences in OH_{exp} and organic mass loading between the two studies."

- funding acknowledgement seems to be missing.

The development of the APPA was supported by internal university funding sources and not a funding agency.