Supplement of

Ethylamine-Driven Amination of Organic Particles: Mechanistic Insights via Key Intermediates Identification

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Section S1. Supporting experimental data

This section presents supporting experimental data consisting of particle size distributions (Fig. S1), reaction products distributions (Figs. S2 and S3), kinetic profiles (Fig. S4), APPI-HRMS (Fig. S5), and uptake coefficients (Figs. S6 and S7).

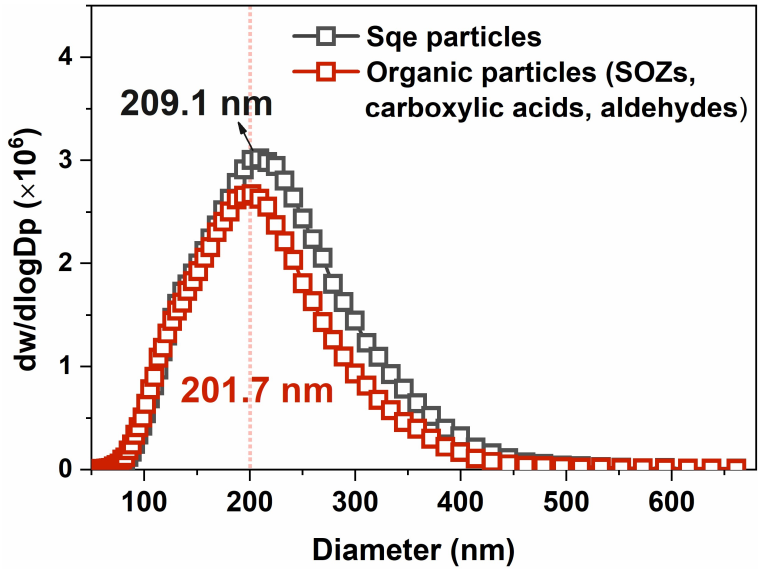

Figure S1. Size distributions of Sqe particles and organic particles measured by SMPS. The diameters of organic particles (201.7 nm) is comparable to that of Sqe particles (209.1 nm).

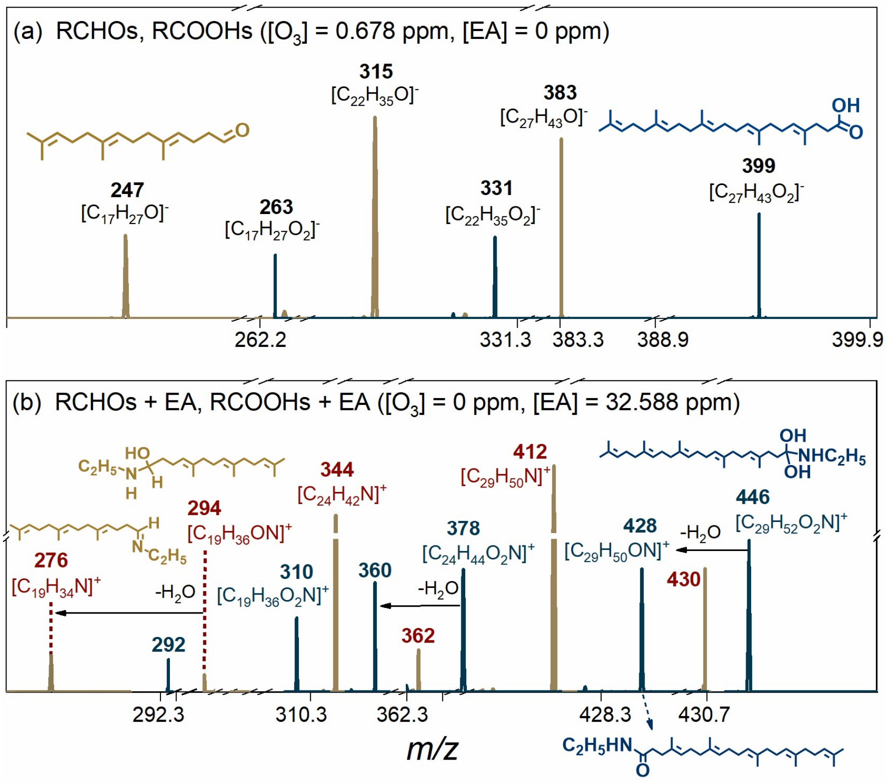

Figure S2. Mass spectra of (a) representative aldehydes (RCHOs) and carboxylic acids (RCOOHs) generated from Sqe ozonolysis in the first flowtube reactor, and (b) their amination products upon ethylamine (EA) exposure in the secondary flowtube reactor.

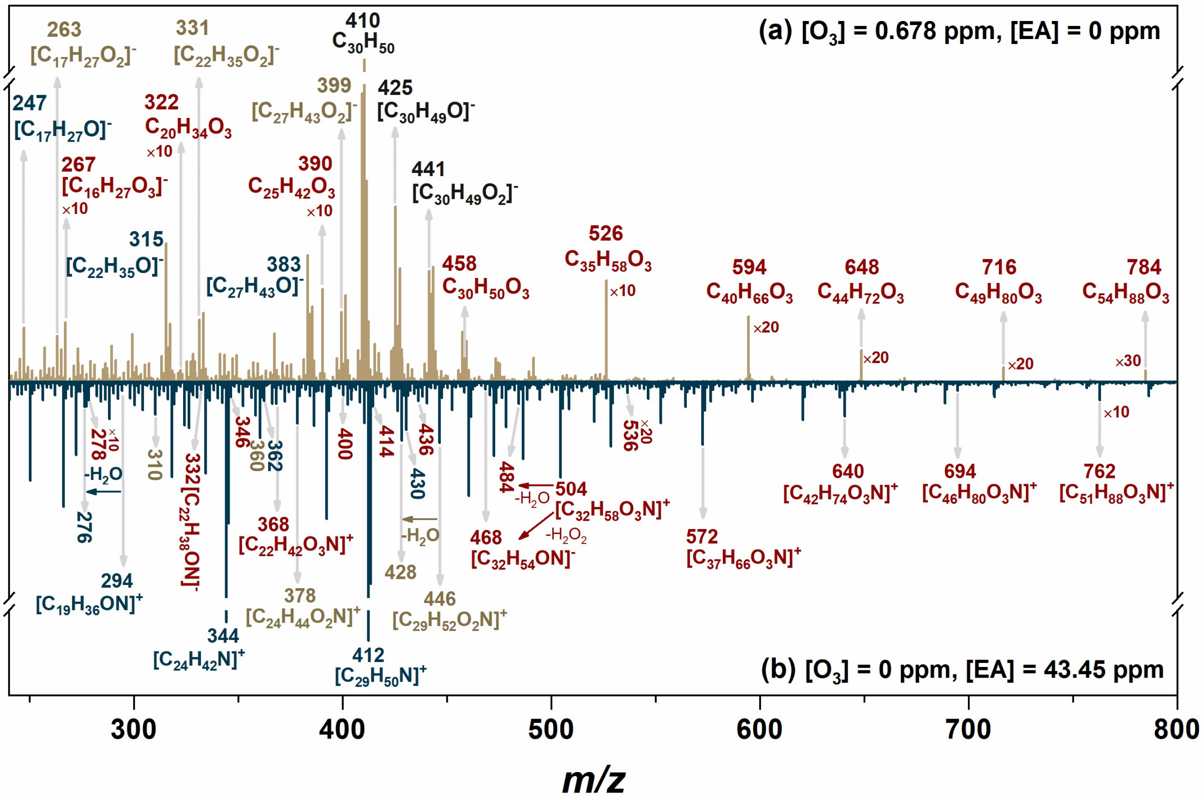

Figure S3. Products distributions from (a) Sqe ozonolysis at 0.678 ppm O_3 in the first flowtube reactor, and (b) subsequent amination reactions with ethylamine ([EA] = 43.45 ppm) in the secondary flowtube reactor.

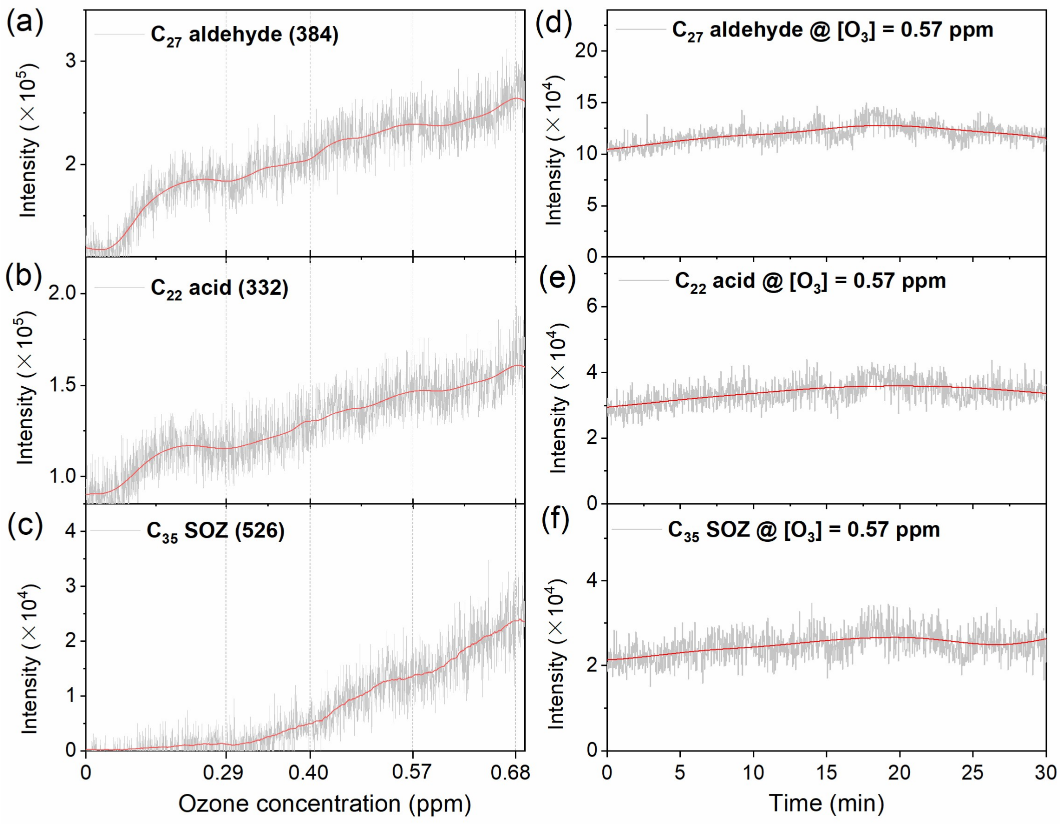

Figure S4. Mass spectral intensities of representative C_{27} aldehyde (*MW* 384), C_{22} carboxylic acid (*MW* 332), and C_{35} SOZ (*MW* 526) in the first flowtube reactor under (a-c) varying O_3 concentrations (0, 0.29, 0.4, 0.57, and 0.68 ppm); as well as (d-f) at fixed O_3 concentration (0.57 ppm).

Figure S5 shows the direct orifice-sampling interface coupled with particle evaporation and photoionization for APPI-HRMS analysis (Liu et al., 2024). The particles flow (800 mL/min) was introduced into the online detection system through a quartz glass tube (235 mm long × 8 mm i.d.), featuring a 0.5 mm sampling orifice. Particles are vaporized by a heater positioned outside the tube (maintained at 180 °C) ensure particle vaporization prior to ionization. A vacuum ultraviolet (VUV) lamp (PKS106, Heraeus, Ltd.) with a photon energy of 10.6 eV (117 nm) provides soft photoionization, minimizing fragmentations during ionization.

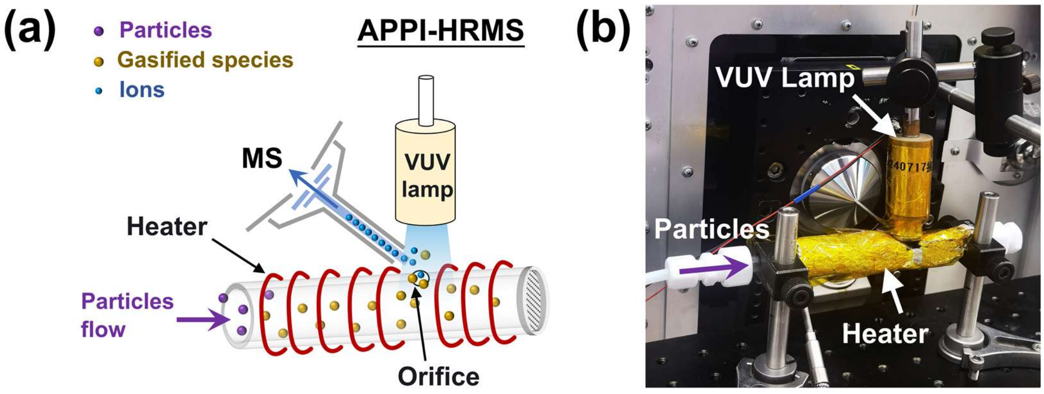

Figure S5. (a) Schematic diagram and (b) photograph of the direct-orifice sampling interface integrated with online APPI-HRMS.(Liu et al., 2024)

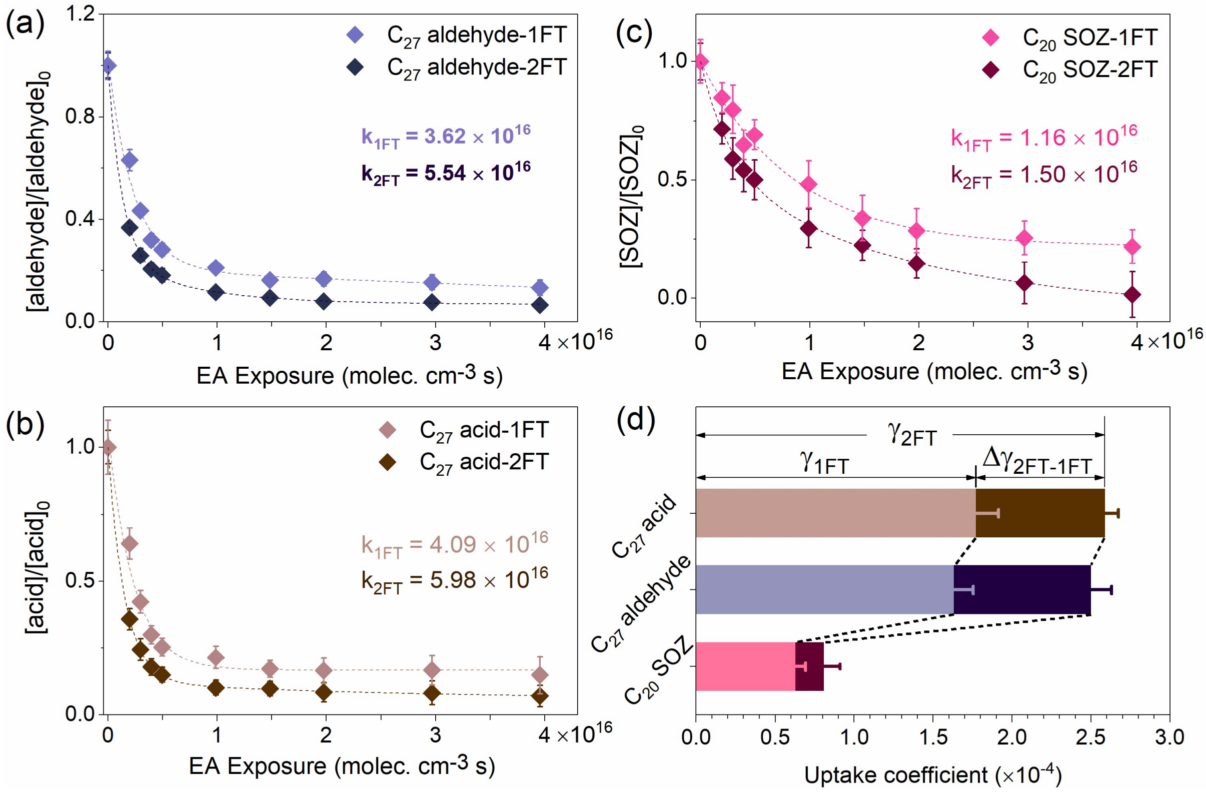

Figure S6. (a-c) The decay kinetics of representative (a) C_{27} aldehyde, (b) C_{27} carboxylic acid, and (c) C_{20} SOZ under control single flowtube experiment (1FT) and tandem flowtube reactor experiment (2FT). The derived decay rates of these organic particles (denoted as k_{1FT} and k_{2FT}) were used to calculate (d) the differential uptake coefficients ($\Delta\gamma_{eff,\ 2FT\text{-}1FT}$), revealing the net reaction contribution in the secondary flowtube reactor.

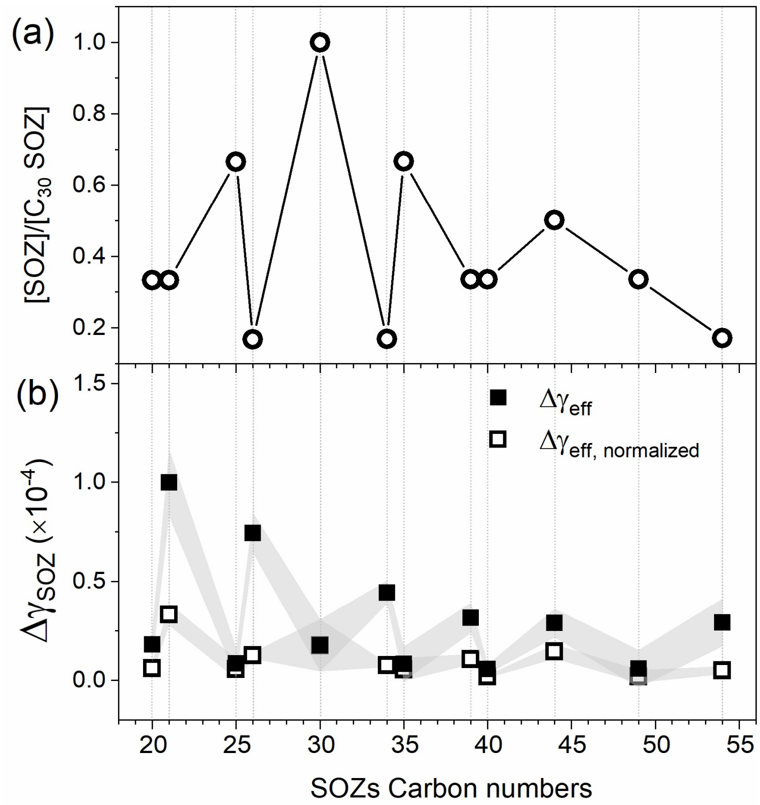

Figure S7. (a) Relative abundances of SOZs normalized to the C_{30} SOZ (maximum concentration) based on data from Ref.(Liu et al., 2024; Heine et al., 2017). (b) Experimentally determined differential uptake coefficients (denoted as $\Delta\gamma_{eff}$) for C_{20} to C_{54} SOZs were normalized by their relative abundances of yield $\Delta\gamma_{eff,\ normalized}$. The reduced differences in $\Delta\gamma_{eff,\ normalized}$ values exhibit compared to original $\Delta\gamma_{eff}$ values demonstrates that the abundance of SOZs influence their heterogeneous reactivity with ethylamine.

Section S2. Reaction mechanisms

This section presents supporting reaction mechanisms, including the ozonolysis reactions of Sqe (Figs. S8-S10), reactions between SOZs with amines (Figs. S11-S13), and reactions between C_{17} aldehyde (or carboxylic acid) with ethylamine (Fig. S14).

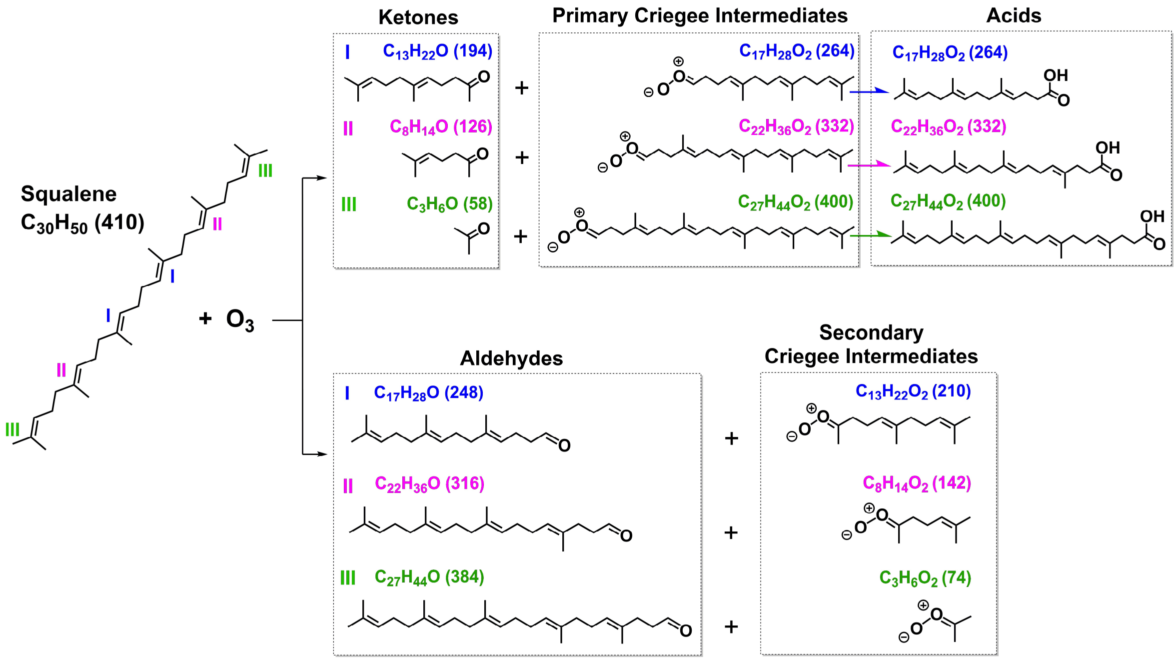

Figure S8. Ozonolysis of squalene (Sqe) yields aldehydes (*MW* 248, 316, and 384), ketones (*MW* 194, 126, and 58), and CIs. The isomerization reactions of primary CIs produce carboxylic acids (*MW* 264, 332, and 400).(Heine et al., 2017)

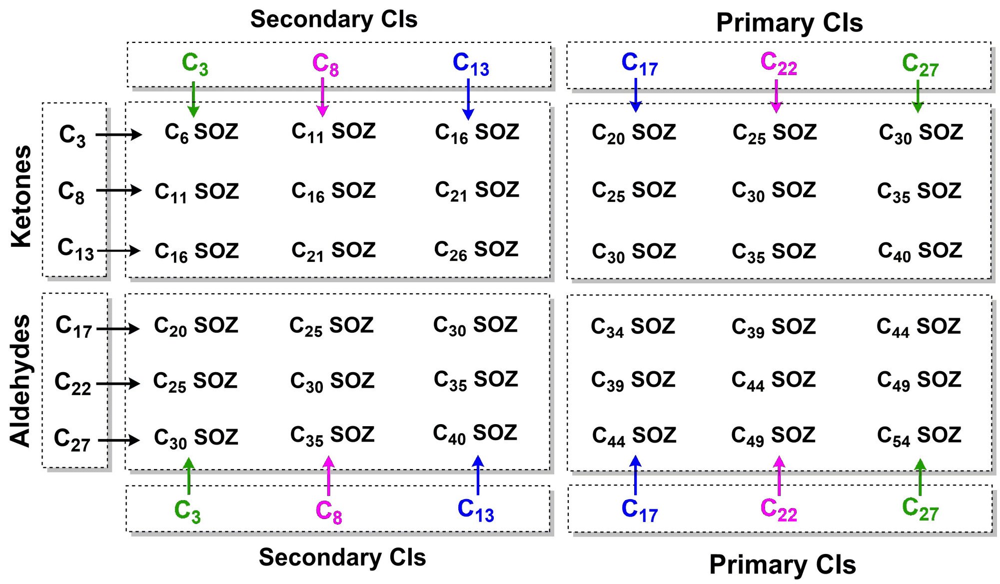

Figure S9. Bimolecular reactions between primary (or secondary) CIs and aldehydes (or ketones) leading to the formation of SOZs.

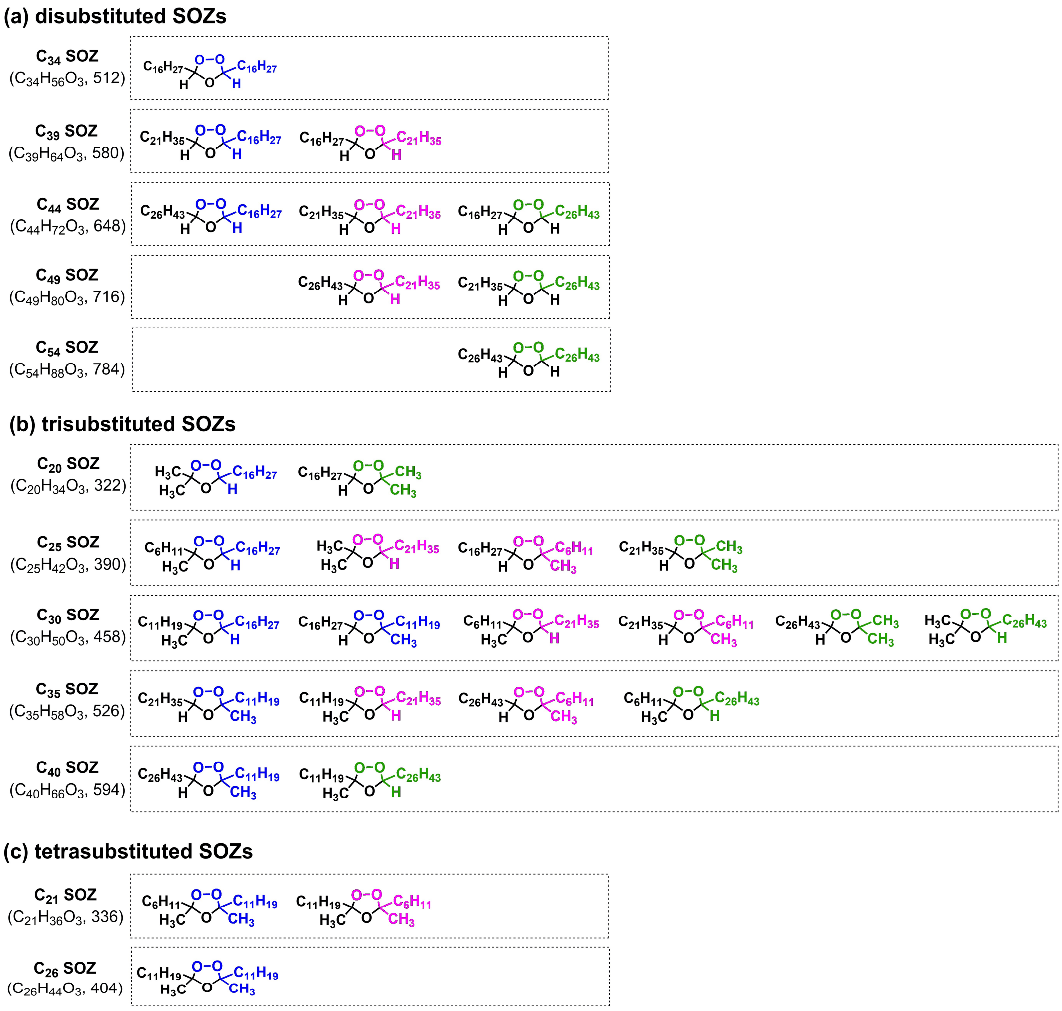

Figure S10. Structural classification of SOZs according to the number of alkyl substituents: (a) disubstituted (C_{34}, C_{39}, C_{44}, C_{49} and C_{54}), (b) trisubstituted (C_{20}, C_{25}, C_{30}, C_{35} and C_{40}), and (c) tetrasubstituted (C_{21} and C_{26}) SOZs.

Figure S11 illustrates established reaction mechanisms of SOZs with amines, highlighting mechanistic controversies (Qiu et al., 2024; Zahardis et al., 2008; Almatarneh et al., 2020; Jørgensen and Gross, 2009; Na et al., 2006). Zahardis et al. (2008) identified a reaction pathway of a C_{18} SOZ with octadecylamine to generate a hydroxyl peroxyamine, which undergoes dehydration to yield nonanal and a C_{27} amide. In contrast, Almatarneh et al. (2020), Jørgensen and Gross (2009), and Na et al. (2006) proposed the formation of amino hydroperoxides in SOZ + amine reactions (Almatarneh et al., 2020; Jørgensen and Gross, 2009). Qiu et al. (2024) characterized a direct amination pathway where cyclic SOZ reacts with ethylamine via concerted H_2O elimination, producing linear amination product (Fig. S11f). Additional pathways have been also proposed in Refs (Almatarneh et al., 2020; Jørgensen and Gross, 2009; Na et al., 2006) (Figs. S11g and S11h).

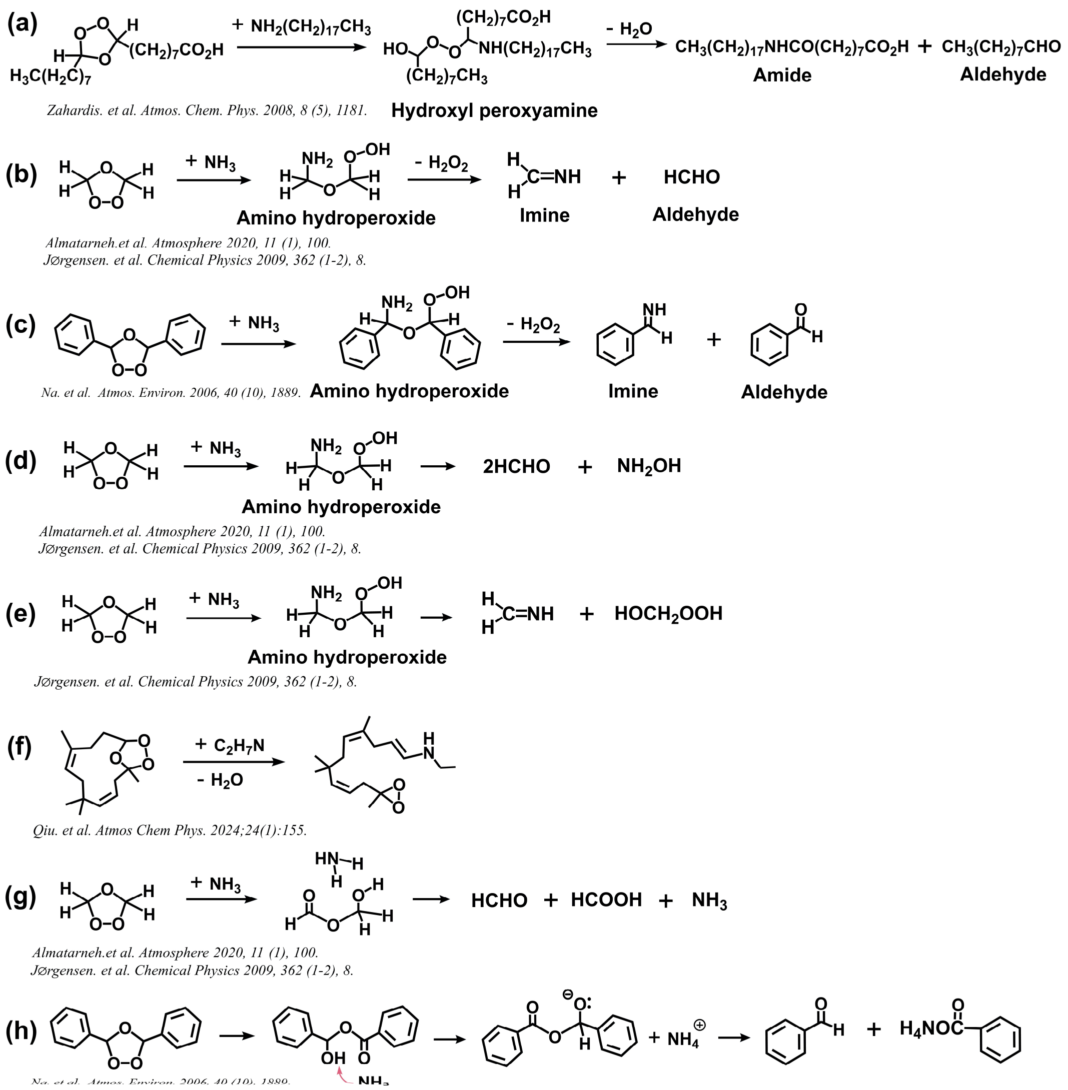

Figure S11. Reaction mechanisms of SOZs with amines as established in previous studies (Qiu et al., 2024; Zahardis et al., 2008; Almatarneh et al., 2020; Jørgensen and Gross, 2009; Na et al., 2006).

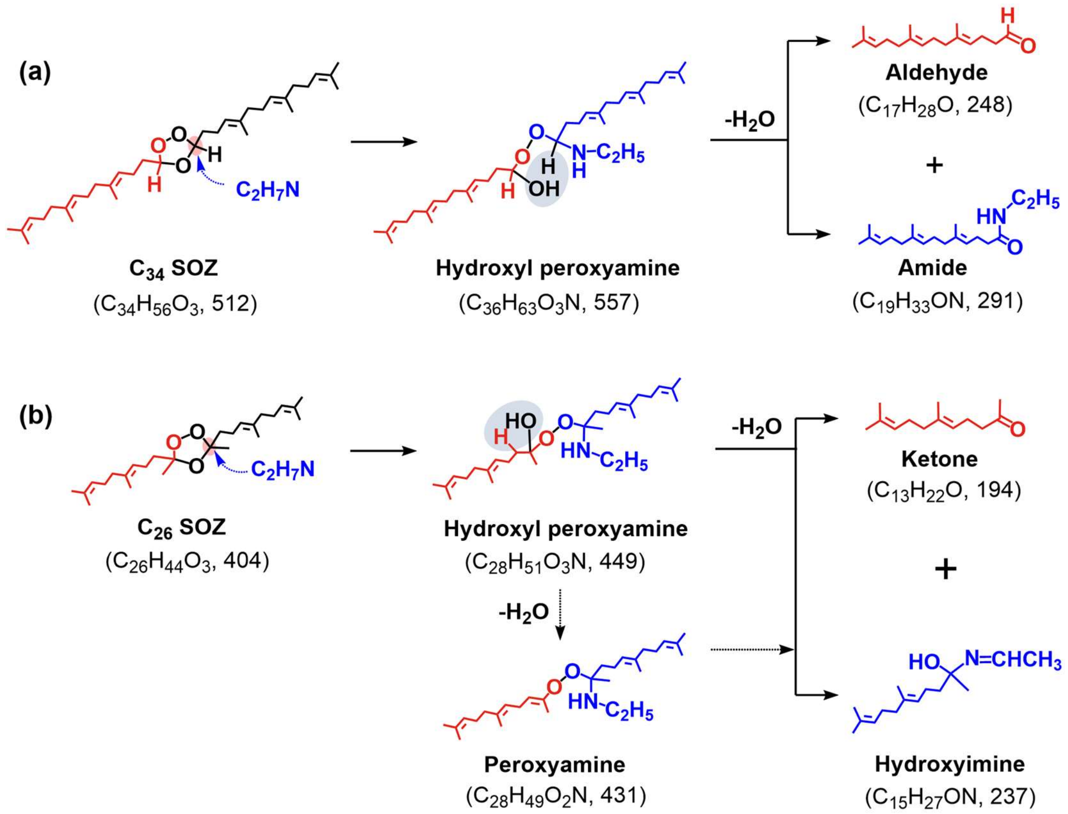

Figure S12. Reaction pathways of representative SOZs with varying alkyl substitution patterns: (a) disubstituted (C_{34}) and (b) tetrasubstituted (C_{26}) SOZs upon exposure to ethylamine (C_2H_7N).

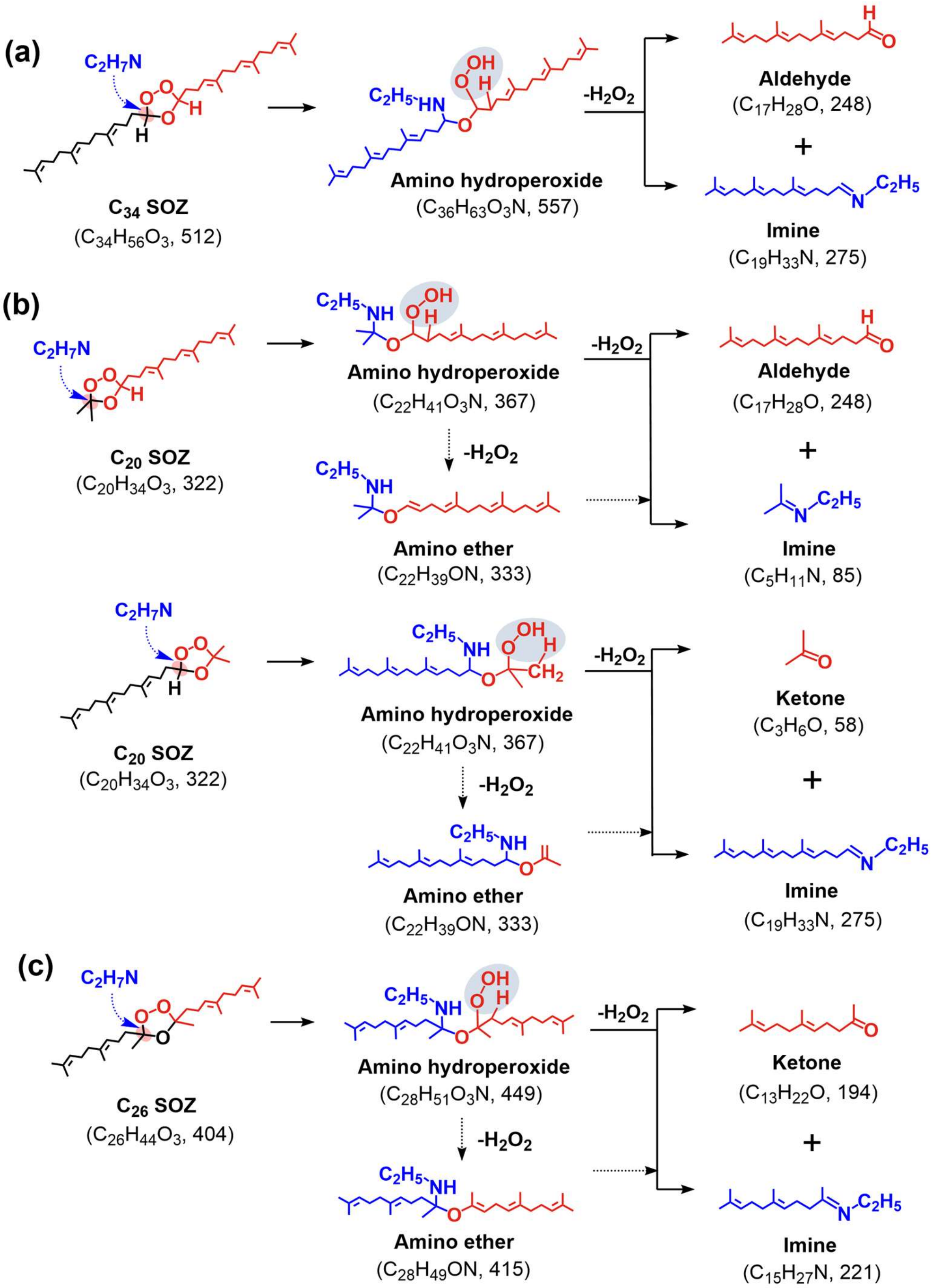

Figure S13. Reaction pathways of representative SOZs with varying alkyl substitution patterns: (a) disubstituted (C_{34}), (b) trisubstituted (C_{20}), and (c) tetrasubstituted (C_{26}) SOZs upon exposure to ethylamine (C_2H_7N).

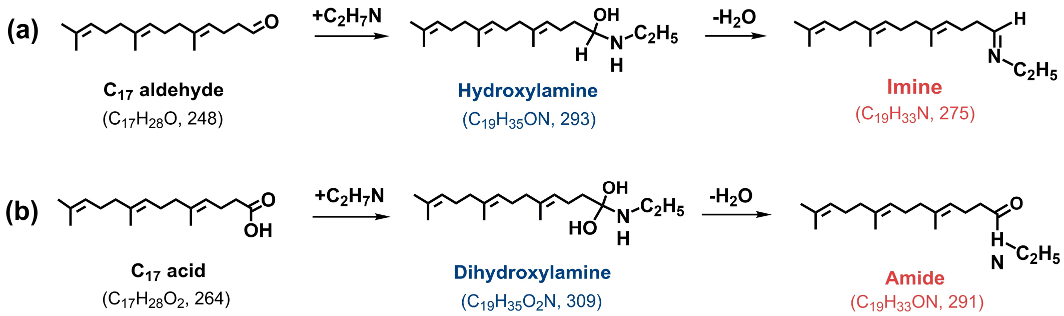

Figure S14. Reaction pathways of (a) C_{17} aldehyde and (b) C_{17} carboxylic acid upon ethylamine exposure.

SI References

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