What’s Eating Ozone? Thermal Reactions between SO₂ and O₃ and Implications for Icy Environments

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Background

• Surface composition of icy objects can be altered by radiolysis/photolysis
• Laboratory studies show radiolysis/photolysis easily forms ozone (O₃) in many different ices
• Few detections of O₃ via remote sensing
• Why the difference?
  – Could O₃ react with other compounds in the ice?

Where to Start?

• Radiolysis prevalent on the Jovian moons
• Condensed O₃ has been detected on Ganymede, Callisto, Europa
  – O₃ only detected on Ganymede
• Sulfur compounds are present on most Jovian satellites
  – Investigate whether O₃ and SO₂ react in H₂O-ice under relevant conditions

Approach

• Grow H₂O + SO₂ + O₃ (75-21-4) mixtures at 50 K
• Warm ices, while monitoring with IR spectroscopy
• To synthesize O₃
  • Strike ~100 Torr of O₂ with Tesla coil
  • Trap O₃ in liquid N₂

O₃ Experiments

IR Spectrum

H₂O + SO₂ + O₃ ice sample

Gold Mirror Surface (5 cm²)

Proton radiation source delivers ~1 MeV H⁺

Mass Spectrometer

10 - 300 K ~ 10⁻⁴ torr

Results
IR Spectra During Warming

- $H_2O + SO_2 + O_3$ ice
  - Deposit at 50 K
  - Warm to 120 K (1 K/ min)
- Main Sulfur Products
  - $HSO_3^-$ (80 – 100 K)
  - $S_2O_5^{2-}$ (80 – 100 K)
  - $HSO_4^-$ (> 100 K)

Decrease in Ozone vs. Temp

- Reaction begins near 100 K
- Rate increases with temperature
- At 130 K, $O_3$ reaches noise level in a few hours
- Temperatures are well within those observed for Jovian icy satellites

Implications for Callisto

- Condensed $O_2$ on trailing side but no $O_3$
- $SO_2$ is present but more abundant on leading side
- $O_3$ on trailing side would be consumed by $SO_2$
  - Lack of $O_3$ on Callisto
  - Lower abundance of $SO_2$ on trailing side

Summary and More Implications

- $O_3$ and $SO_2$ react readily above 100 K
  - They won’t be found in same vicinity
- Callisto
  - Lack of ozone in trailing hemisphere
  - Spatial distribution of $SO_2$
- Possibly relevant to other icy bodies
  - Mass spectrometer on Rosetta detected $O_3$ in comet coma but no $O_3$
  - No $O_3$ detected in ISM and lower than expected abundance of identifiable sulfur compounds
- Future work will focus on whether other compounds similarly reactive with ozone

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http://science.gsfc.nasa.gov/691/cosmicice/