Experimental evidence for NH$_2$OH formation via NO hydrogenation in dark clouds

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Nitrogen chemistry in the ISM

- 5th most abundant element with >50 nitrogen species identified in gas phase in space but...
- Nitrogen chemistry is still poorly understood

About Hydroxylamine – NH$_2$OH:
- Its formation was first studied by [1] and [2] by irradiating mixtures of NH$_3$ and H$_2$O ices
- Suggested in its role towards formation of interstellar amino acids [3]
- Astrobiology implications

NH$_2$OH formation mechanisms

- Nitric oxide (NO) possibly converted to NH$_2$OH through hydrogenation under quiescent cloud conditions Charnley et al. (2001) [4]:
  \[ \text{NO} \rightarrow \text{HNO} \rightarrow \text{H}_2\text{NO} \rightarrow \text{NH}_2\text{OH} \]
  ...but no experimental evidence for this process until 2012

Here we present a study of the formation of hydroxylamine via the non-energetic route NO + H (D) on crystalline H$_2$O and amorphous silicate under conditions relevant to interstellar dense clouds [5, 6].

In the Laboratory: set-up and methods

1) NO + H deposited on silicate or water ice samples kept at 10 K under monolayer regime
2) RAIR spectroscopy: detection in situ
3) Temperature-programmed desorption (TPD) Mass spectroscopy

TPD/FT-RAIRS Results & Reaction Pathways

TPD mass spectra as a function of temperature during a TPD experiment after 1 ML of NO and 3 EML of H-atoms on amorphous silicate at 10 K.

Conclusions

- Hydroxylamine (NH$_2$OH) is formed fast @ 10K by sequential hydrogenation of NO without external energetic input and no apparent activation barrier
- NH$_2$OH is produced at comparable rates on all surfaces and regardless of the hydrogen isotope used (H/D)
- Due to its high desorption energy, NH$_2$OH remains locked up on the grains and provides a solid-state nitrogen reservoir available at later stages (UV + thermal processing)
- Astrobiology implications: NH$_2$OH is considered one of the precursor molecules of amino acids

References