

Infrared Spectroscopic Analysis of Solid-Phase Carbonic Acid

Ármin Vámi

vami.armin@gmail.com

Székesfehérvári Vasvári Pál Secondary Grammar School, Hungary

1. INTRODUCTION

Carbonic acid (H_2CO_3) is commonly known as a short-lived species in aqueous solutions on Earth; however, recent laboratory and astronomical studies have demonstrated that it can exist in a stable solid phase under low-temperature astrochemical conditions. The investigation of such molecules is essential for understanding chemical processes occurring in interstellar ices, dense molecular clouds, and icy Solar System bodies. Infrared (IR) spectroscopy provides a powerful tool for identifying molecules in these environments due to its sensitivity to molecular vibrational modes. Laboratory-based IR spectroscopic measurements are therefore crucial for interpreting astronomical observations and for building reliable astrochemical models.

2. AIMS

The aim of this research was to investigate the formation, stability, and spectroscopic characteristics of carbonic acid in solid and gas phases under astrophysically relevant conditions. The study sought to determine whether carbonic acid remains stable during sublimation and whether it can be detected in the gas phase, thereby supporting recent astronomical observations and contributing reliable laboratory reference data.

3. METHODS AND MATERIALS

Experiments were carried out using the VIZSLA (Versatile Ice Zigzag Sublimation Setup for Laboratory Astrochemistry) ultra-high-vacuum simulation chamber. An ice mixture of carbon dioxide and water in a 3.5:1 ratio was deposited onto a gold-coated silver substrate at 10 K. The samples were irradiated with 5 keV electrons to simulate cosmic radiation, and chemical changes were monitored using Fourier-transform infrared (FTIR) spectroscopy. Temperature-programmed desorption (TPD) experiments were also performed. These were done by heating the sample from 10 K to 300 K at a rate of 1 K/min. In selected experiments, sublimated species were recondensed onto a secondary cold substrate and analyzed using argon matrix isolation.

4. RESULTS

Electron irradiation of the $\text{CO}_2\text{-H}_2\text{O}$ ice mixture resulted in the appearance of new absorption bands in the IR spectrum. These bands were assigned to carbonic acid, carbon monoxide, carbon trioxide, and ozone. Difference

spectra clearly showed the formation of carbonic acid, with characteristic absorption features at 1724, 1480, and 1290 cm^{-1} . During TPD experiments, volatile precursor species sublimated below 200 K, while carbonic acid ice remained stable up to 260–280 K. Matrix-isolation measurements revealed the presence of both *cis-cis* and *cis-trans* conformers of carbonic acid, confirming that the molecule remains stable during sublimation and exists temporarily in the gas phase.

5. DISCUSSION

The results demonstrate that carbonic acid can form efficiently in irradiated astrophysical ice analogues and remain stable at elevated temperatures compared to its precursors. The detection of gas-phase carbonic acid during sublimation supports recent astronomical findings and confirms that laboratory IR spectra can serve as reliable references for space-based observations. These findings have implications for understanding chemical evolution in interstellar ices and on icy planetary bodies.

6. CONCLUSIONS

This study provides experimental evidence for the formation and stability of carbonic acid under simulated astrochemical conditions. The obtained infrared spectra and thermal behavior data contribute to the identification of carbonic acid in astronomical environments and improve our understanding of carbon chemistry in space.

7. ACKNOWLEDGEMENT

I gratefully acknowledge the support of Dr. Sándor Góbi and the ELTE Institute of Chemistry for providing the opportunity and facilities for this research.

8. REFERENCES

- <https://doi.org/10.1016/j.cplett.2007.10.094>
- <https://doi.org/10.3847/1538-4357/ace523>
- <https://doi.org/10.1002/cphc.202500282>
- <https://elo.hu/ir-spectroscopy-az-infravoros-spektroszkopia-modszere/>
- <https://aip.scitation.org/doi/10.1063/5.0061762>