Activation of Two Weak IR Fundamentals of Solid Methane: The Importance of Amorphous Ices

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The Cosmic Ice Laboratory

radiation chemistry
thermal chemistry
photochemistry
reference spectra
IR band strengths
optical constants
refractive indices
ice densities

Molecular Abundances

Measure band intensities
BUT still need
lab spectra for comparison.

Want to convert band area into # ice molecules

\[ A' = \frac{n \cdot k (\text{optical constants})}{\text{thickness} \times \text{no. density}} \]

And then apply

\[ N, \text{column density} = \int \tau \, d\tilde{\nu} / A' \]

Optical Constants and Band Strengths of Ices – v. 4

HCN NC-CN HCC-CN
CH₃CN CH₃CH₂CN
C₂H₂ C₂H₄ C₂H₆ CH₄

Hudson et al., Icarus, 2014a and 2014b
Moore, Hudson et al., ApJL, 2010

The Phase Problem

amorphous ice
crystalline ice
low T warming or high T
slow formation fast formation

HH₂ CH₃ CH₄ 298 K CH₃ CH₄
10 K substrate
IR Selection Rules Vary

gas phase  
crystalline phase  
amorphous phase  
liquid phase

Solid CH₄ – 10 K Survey Spectrum

v₃  
v₄

Absorbance

Wavenumber (cm⁻¹)

10 K CH₄ from Five Labs

10 K crystalline phase II  
10 K amorphous phase

10 K CH₄ from Five Labs

7.58 μm  
7.81 μm

v₄ Band of CH₄

Crystalline Phase I, 30 K  
Crystalline Phase II, 10 K  
Amorphous Phase, 10 K

Solid CH₄ – Mid IR

30 K crystalline phase I  
10 K crystalline phase II  
10 K amorphous phase
Solid H$_2$O + CH$_4$ Mixture

$\sim$15 K

CH$_4$ – The Forbidden Transitions

10 K crystalline phase I

10 K amorphous phase

Relative Intensities

A chemistry check

Isoelectronic Species

$\text{NH}_4\text{SH and Jupiter}$

NH$_3$ + H$_2$S $\rightarrow$ NH$_4^+$ + HS$^-$

amorphous $\rightarrow$ crystallize $\rightarrow$ amorphous

Why Study Amorphous Ices?

- Found in Solar System and interstellar medium
- Irradiated solids are amorphous
- First approx. for icy mixtures (> 1 component)
- “Fallback” data for band strengths and spectra
- Provides confidence in understanding of ices
- Band strengths to compare to calculations
- Terrestrial applications – forbidden transitions
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http://science.gsfc.nasa.gov/691/cosmicice/

Coming in August 2016
Frontiers of Solar System Chemistry – Planets to Comets and Beyond
Reggie Hudson & Stefanie Milam