

Formation, Destruction, and Spectra of Extraterrestrial Molecules

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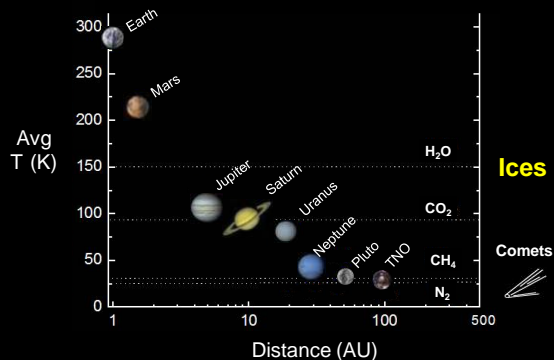
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Temperatures in the Solar System



Some Icy Worlds and Icy Molecules



Europa
(Jupiter)

Enceladus
(Saturn)

Miranda
(Uranus)

Triton
(Neptune)

Charon
(Pluto)

H_2O
 CO_2

H_2O_2
 CO

N_2
 CH_4

NH_3
 C_2H_6

H_2S
 O_2

SO_2
 O_3

Some Problems and Questions

Expect hydrate formation from some of the known molecules

Data available usually for "high" T and ≥ 1 atm

Data available usually for samples made from liquids

Our Laboratory Approach

Prepare hydrates - from ices at low T

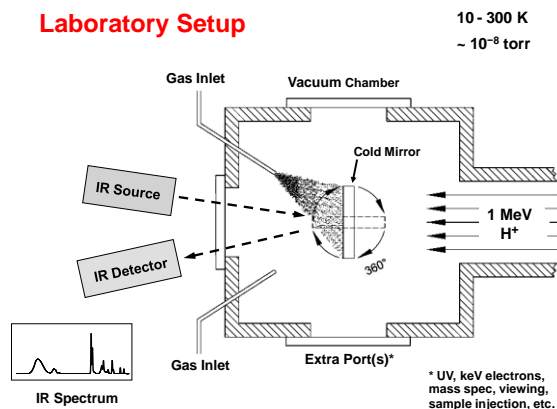
Characterize hydrates - record IR spectra

Follow hydrate evolution - thermal and radiolytic

Reaction products

Apply results - planetary science, astrobiology, etc.

Laboratory Setup

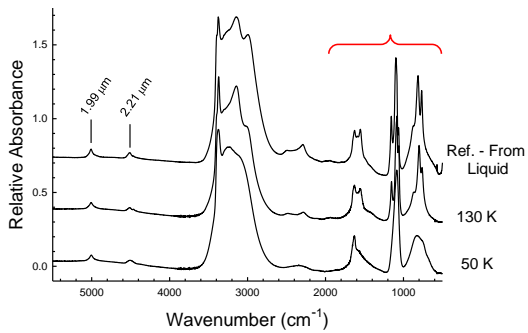
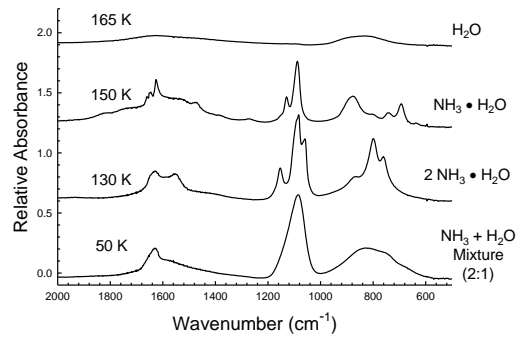
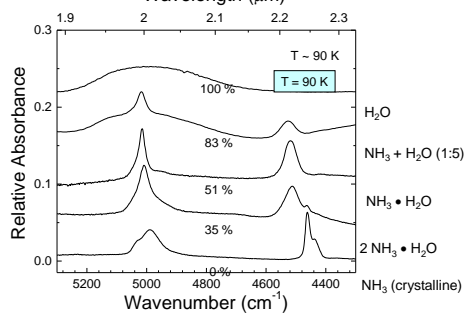


Some Ammonia-Containing Ices

NH_3	$\text{NH}_3 + \text{H}_2\text{O}$	NH_4^+
ammonia	amorphous mixtures	ammonium
$2 \text{NH}_3 \cdot \text{H}_2\text{O}$	$\text{NH}_3 \cdot \text{H}_2\text{O}$	$\text{NH}_3 \cdot 2 \text{H}_2\text{O}$
hemihydrate	monohydrate	dihydrate

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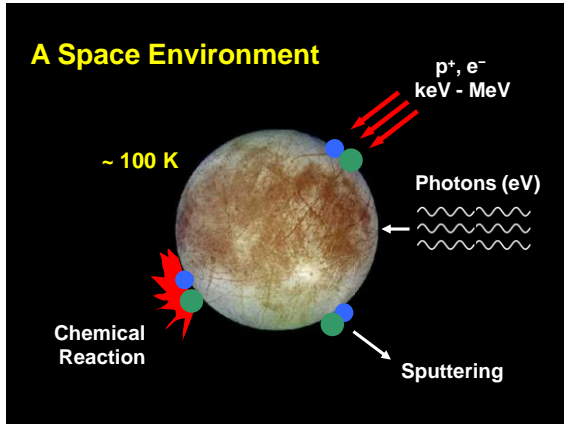
Comparison of $2 \text{NH}_3 \cdot \text{H}_2\text{O}$ IcesThermal Evolution of $2 \text{NH}_3 \cdot \text{H}_2\text{O}$ Influence of H_2O on NH_3 Near-IR Bands

Some Ammonia Results

Ices $\xrightarrow{\Delta}$ Hydrates $\xrightarrow{\Delta}$ Deamination

Near-IR bands' positions vary almost linearly with H_2O conc. for $> \sim 25\%$ H_2O

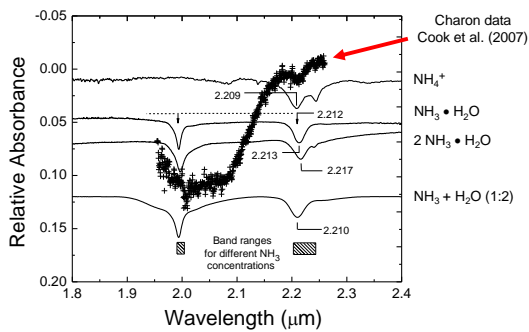
Need more than band positions to identify hydrates



Some Radiation Results

- Loss of NH_3
- Near-IR band positions hardly change
- Amorphization of hydrate
- NH_4^+ formation (4527 cm^{-1} , $2.209 \mu\text{m}$)
- Timescales

Some Spectral Comparisons



Sulfur-Related Hydrates

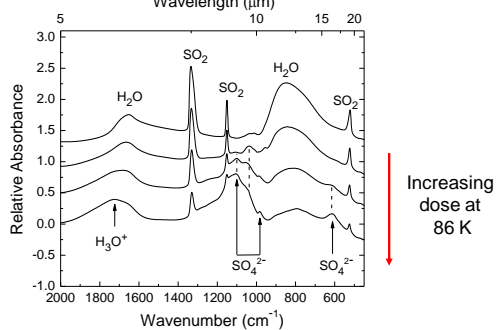
Sulfuric Acid on Europa and the Radiolytic Sulfur Cycle

R. W. Carlson,^{1*} R. E. Johnson,² H. S. Anderson³

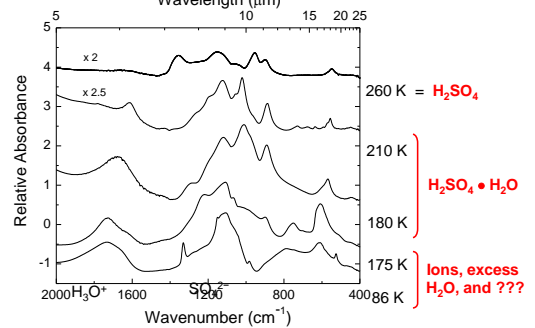
(Ref: *Science*, 1999)



Irradiation gives ions: H_3O^+ , SO_4^{2-} , ...



Warm to get hydrate and more



Some Conclusions

Ices can form hydrates on warming.

Hydrates can change composition on warming.

Radiation alters molecules and can lead to subsequent hydrate formation.

These effects appear in IR spectra.

Need to push experiments out into the near IR!



Acknowledgments



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