Characteristics and Stability of Chlorate Salt Solutions with Applications to Mars

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Introduction

- Chlorides and perchlorates found on Mars [1]
- Investigated perchlorate evaporation rates and eutectic temperatures and concentrations [2]
- Calculated chlorine oxidation states stability diagrams [3]
- Evidence for presence of intermediate oxidation states of chlorine on Mars
- Very little known regarding behavior of these salts in solution, especially at low temperatures

Methods

- Evaporation experiments performed in a Martian simulation chamber (Fig. 1A)
  - CO_2 atmosphere
  - 7 mbar
  - Temperatures between 256 and 267 K
  - Relative Humidity ≤ 1%
- Eutectic experiments performed by freezing solution with liquid nitrogen and monitoring conductivity of salt solution as it melts (Fig. 1B)

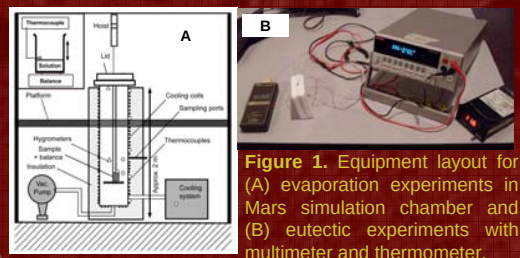

Figure 1. Equipment layout for (A) evaporation experiments in Mars simulation chamber and (B) eutectic experiments with multimeter and thermometer.

References

[1]Hecht, M. H. et al. (2009) *Science* **325**, 5936, pp. 64-67. [2] Chevrier, V. F. et al. (2009), *GRL*, **36**, L10202, doi:10.1029/2009GL037497. [3] Chevrier,V. F. and J. Hanley (2009), *New Martian Chemistry Workshop*. [4] Ingersoll, A. P. (1970), *Science, 168*, 972-973.

Results and Discussion

Evaporation Rates

- 20, 30, 40, and 50 wt% concentrations of $NaClO_3$
- Rates range from 0.14 mm h^{-1} (50 wt% at 258 K) to 0.44 mm h^{-1} (20 wt% at 264 K)
- Rates directly related to temperature and inversely related to concentration
- Results suggest that $NaClO_3$ in a liquid water solution with a depth of 1 m could last 222 sols at 256 K and 125 sols at 267 K
- Theoretical curves used to predict experimental data points

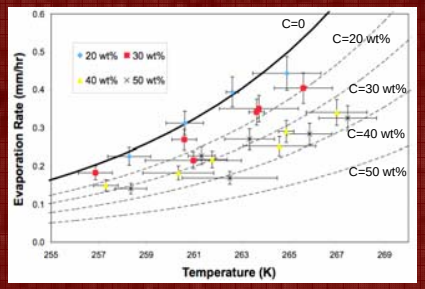

Figure 2. Evaporation rate of $NaClO_3$ as a function of sample temperature and concentration. Dashed lines are theoretical evaporation rates for each concentration, calculated from modified Ingersoll equation [4] and Pitzer model. The solid line is for supercooled liquid water.

Eutectics

- Discontinuity in rate of change of conductivity implies a phase change, indicates eutectic temperature
- Measured eutectic temperatures

$Mg(ClO_4)_2$	$NaClO_4$	$NaClO_3$	$NaClO_2$	NaClO
44 wt%	52 wt%	39 wt%	40 wt%	13 wt%
219 K	240 K	247 K	232 K	~252 K

- $Mg(ClO_4)_2$, $NaClO_2$, and NaClO eutectic temperatures in disagreement with thermodynamic calculations
  - $Mg(ClO_4)_2$ shows an unpredicted phase change
  - $NaClO_2$ and NaClO solutions not pure

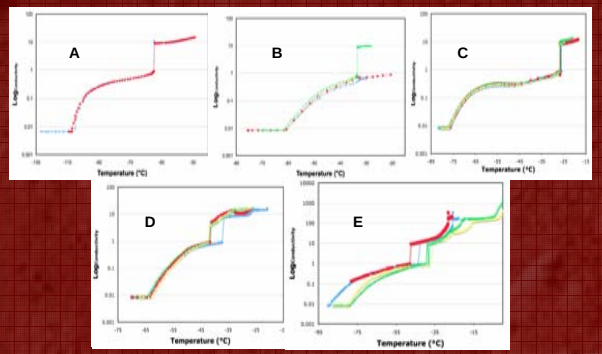

Figure 3. Logarithmic plot of the conductivity of (A) $Mg(ClO_4)_2$, (B) $NaClO_4$, (C) $NaClO_3$, (D) $NaClO_2$, and (E) NaClO, as a function of temperature.

Applications to Mars

- $NaClO_3$ evaporation rates similar to $NaClO_4$ but higher than $Mg(ClO_4)_2$
- $NaClO_3$ eutectic temperature higher than that of $Mg(ClO_4)_2$
- Therefore, $Mg(ClO_4)_2$ probably dominant liquid phase at Phoenix landing site
- Further work should be done on $NaClO_2$ and NaClO to determine properties of solutions and relevance to Mars