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Amorphization of S- and Cl-salts by Martian Dust Activity

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X-ray Amorphous components at Gale

CheMin discovery of X-ray amorphous components

- 19-36 wt% in active and inactive dune materials;
- 20-54 wt% in all mudstones,
- 14-71 wt% in non-altered and altered Stimson samples, [4-8]

Volatile portion in X-ray amorphous components

- Chemistry: SO_3 + Cl+ P_2O_5, H_2O-bearing
- Potential Host: mixed-cation sulfates, phosphate, chloride-perchlorate-chlorate, and small proportions of ferrihydrite [4-8]

SAM analyses (same set of drilled samples)

- crystalline and/or poorly crystalline Mg- and Fe-sulfates,
- associated with water in amorphous phases [9].

Amorphization mechanisms

Early Mars

- volcanic activity, impacts, and acidic weathering.

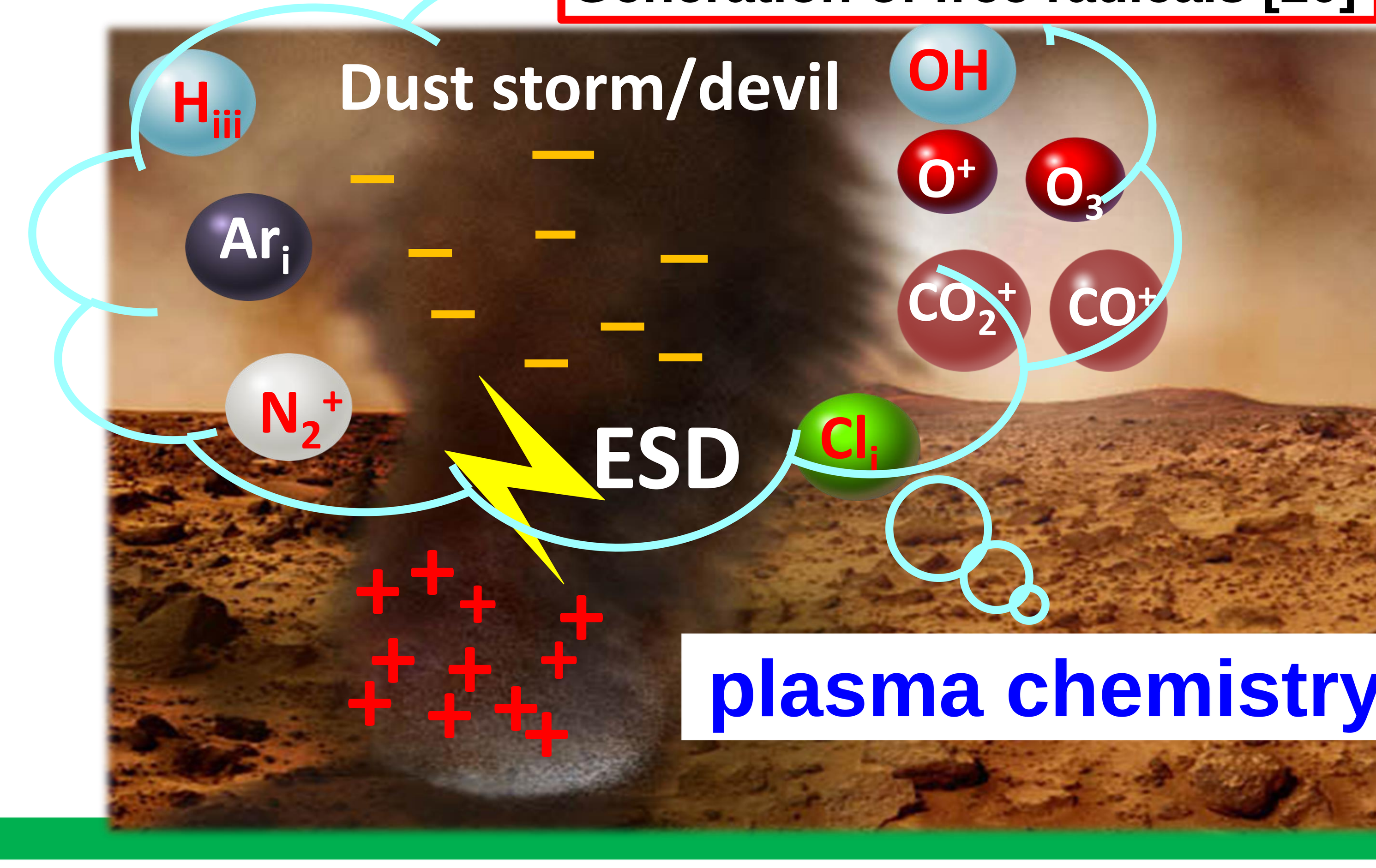
Present-day Mars

- Energetic particles from outer space, e.g., galactic cosmic rays and UVC photons;
- Sudden exposure of subsurface hydrous sulfates to current atmospheric conditions at surface // in Lab: vacuum desiccation of Mg-, Fe^{2+}-, and Fe^{3+}-sulfates [10-13];
- Sudden release of subsurface brines on Mars (i.e., RSL) [18] // in Lab: fast dehydration of brines at very low RH (or vacuum desiccation) at mid-to-low T [14-15] or at extremely low T [16-17].

A different mechanism (ESD)

Martian dust activity → Electrostatic discharge (ESD) → High speed electrons collide with CO_2, O_2, N_2, Ar, H_2O

Generation of free radicals [20]



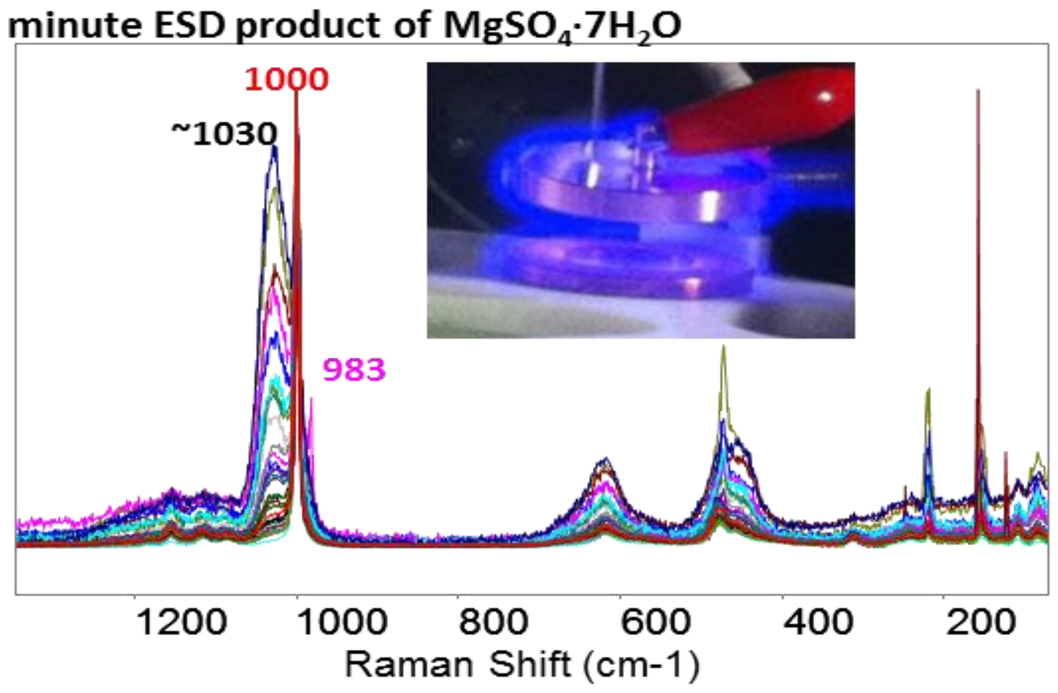
Laboratory ESD experiments & product analyses

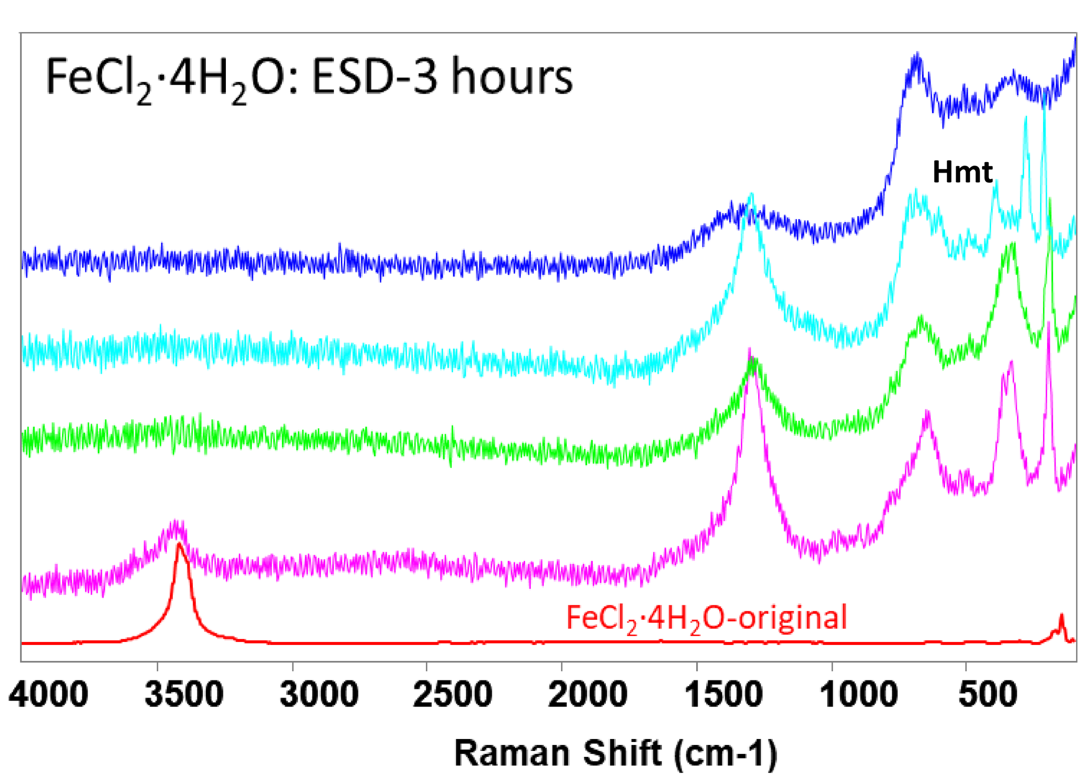
Hydrous & anhydrous sulfates and chlorides : $MgSO_4{\cdot}7H_2O$, $MgSO_4{\cdot}4H_2O$, and $MgSO_4{\cdot}H_2O$; $FeSO_4{\cdot}7H_2O$, $FeSO_4{\cdot}4H_2O$, and $FeSO_4{\cdot}H_2O$; Na_2SO_4, Na_2SO_3, and $NaHSO_3$, $CaSO_4{\cdot}2H_2O$; NaCl, KCl, $MgCl_2{\cdot}6H_2O$, $FeCl_2{\cdot}4H_2O$, $CaCl_2{\cdot}2H_2O$, and $AlCl_3{\cdot}6H_2O$.

ESD experiments in a Mars chamber [19] with CO_2 at 3 mb, and controlled temperatures [22].

Raman: dehydration, amorphization, oxidation

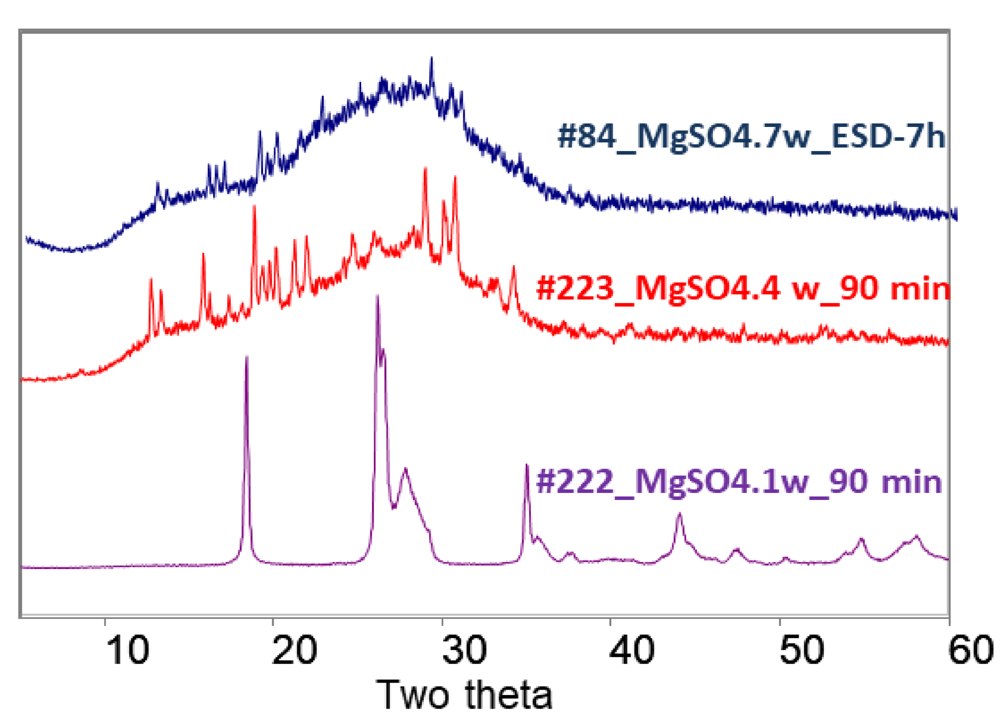
Figure 1. Raman spectra from multi-spots on 15 minute ESD product of $MgSO_4{\cdot}7H_2O$

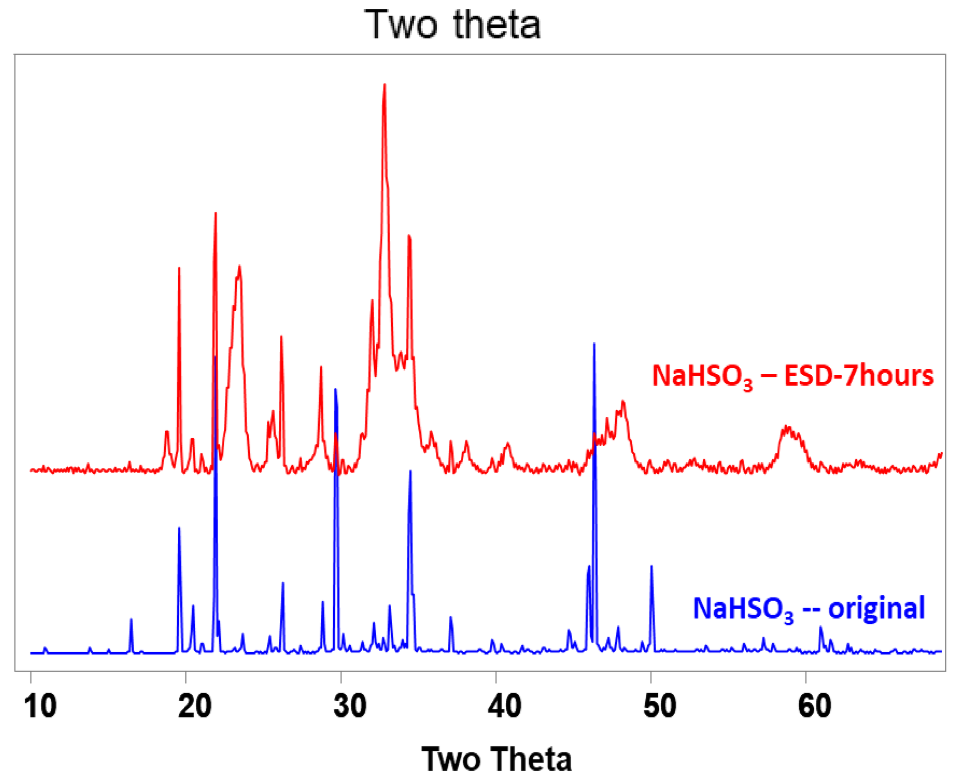




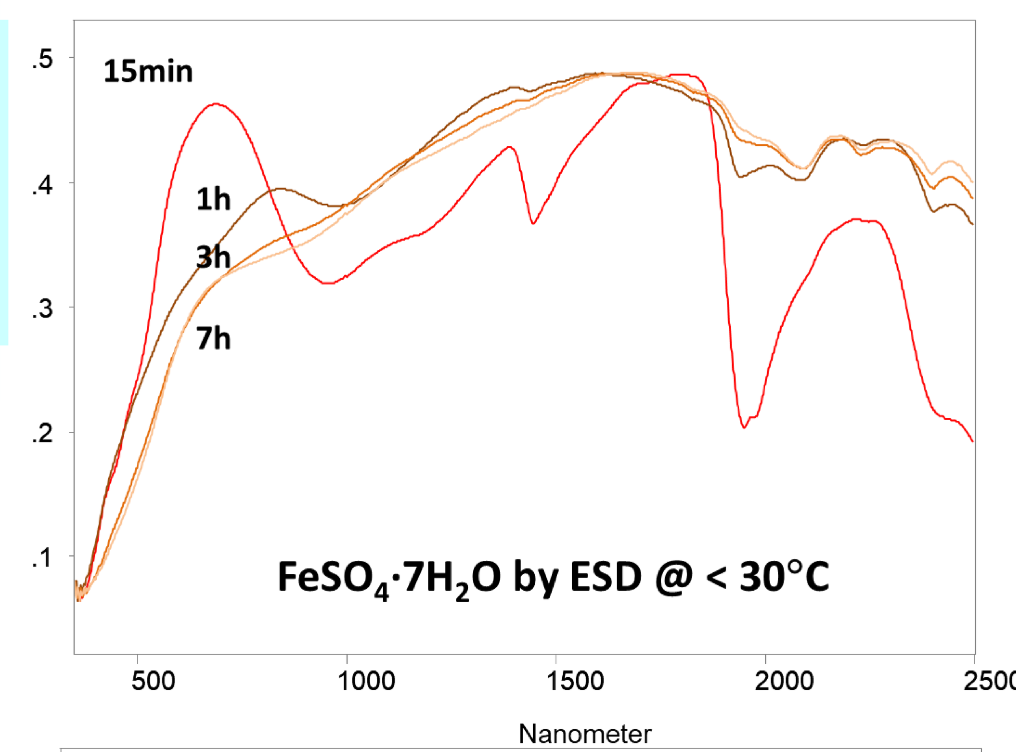
XRD: amorphization

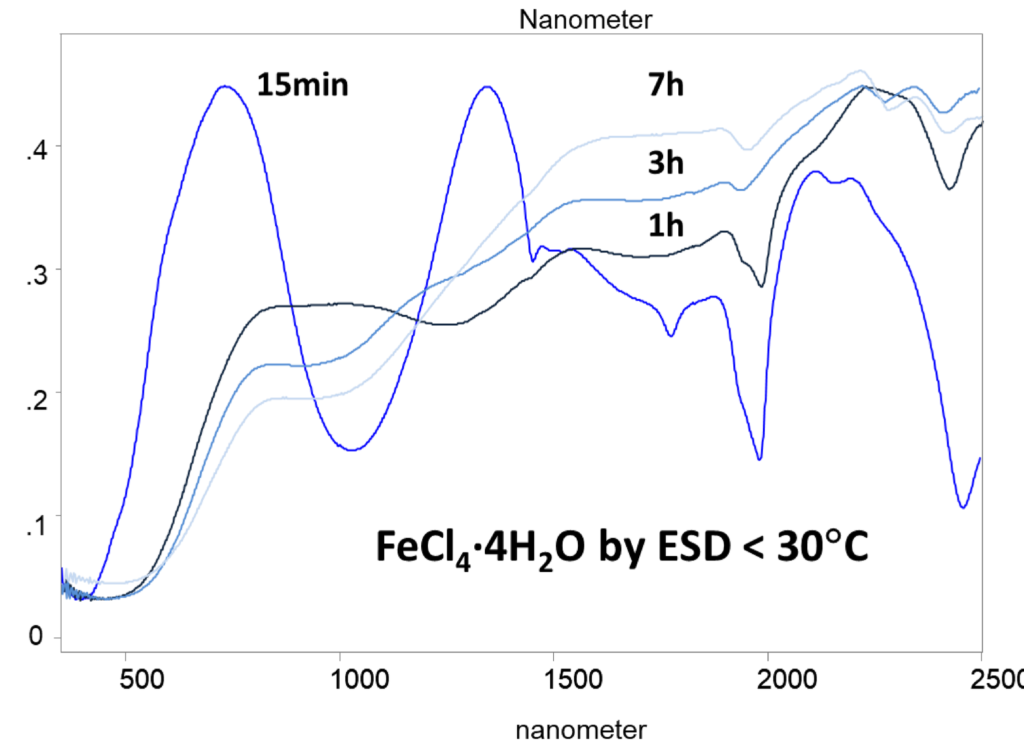
Figure 2. XRD patterns of ESD products from $MgSO_4{\cdot}7H_2O$, $MgSO_4{\cdot}4H_2O$, $MgSO_4{\cdot}H_2O$



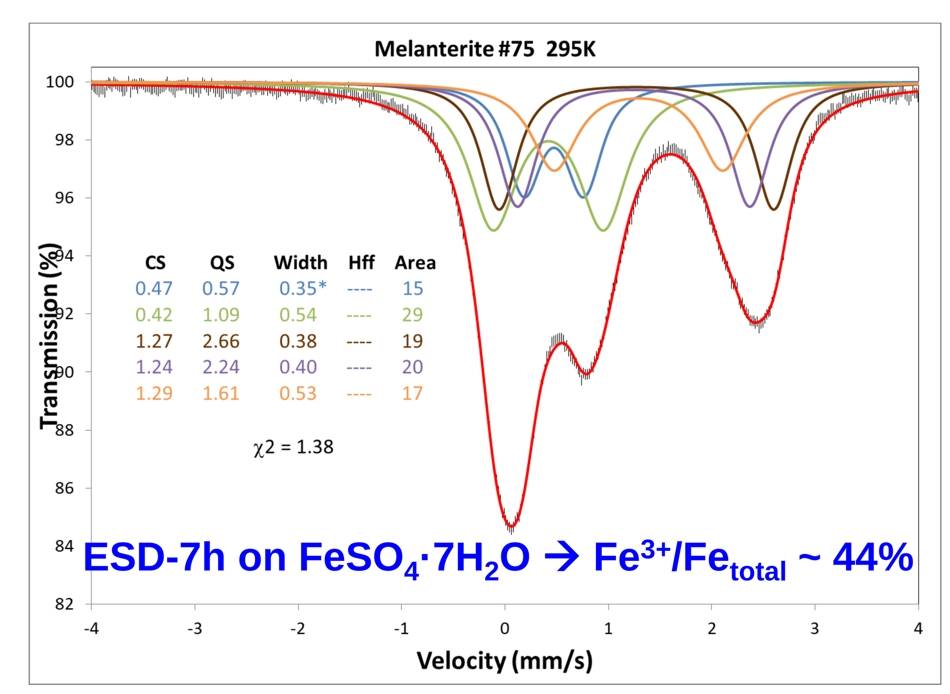


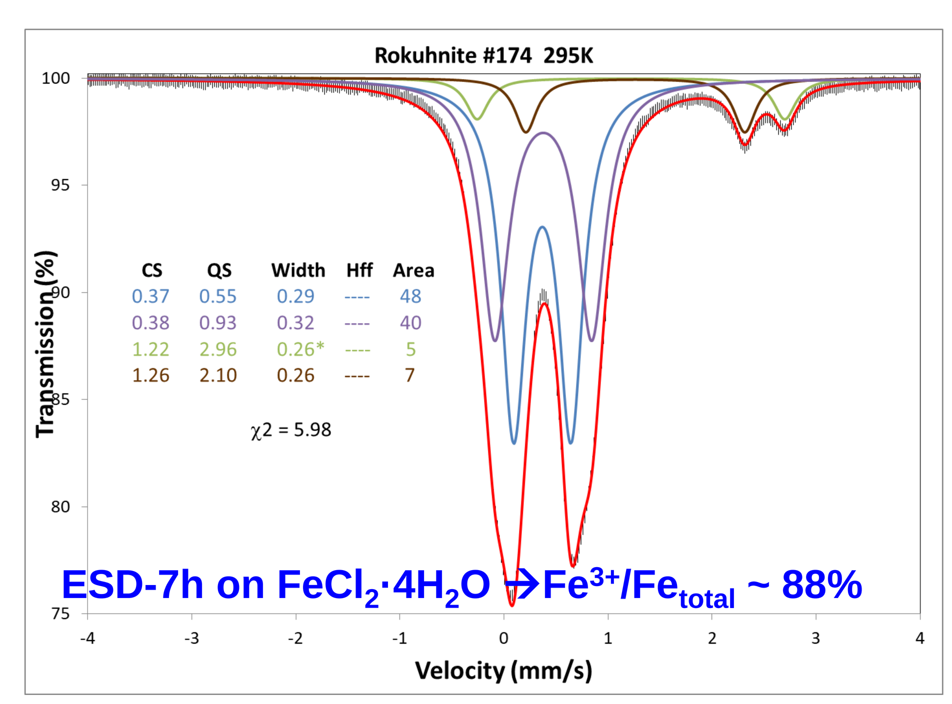
Vis-NIR: dehydration





Mössbauer: oxidation





Conclusion

- The overall effects of ESD on hydrous salts are **dehydration, amorphization, and oxidation;**
- The amorphous hydrous sulfates and chlorides generated during martian dust activities can contribute **to the volatile portion of X-ray amorphous components found at Gale crater;**
- The amorphous components may exist in surface materials **all over Mars.**

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References: [1] Blake et al., *Science,* (2013), [2] Bish et al., *Science,* (2013), [3] Vaniman et al., *Science,* (2013) [4] Morris, et al., *PNAS,* (2016); [5] Achilles et al., *JGR,* (2017); [6] Rampe et al., *EPSL,* (2017); [7] Yen et al., *EPSL,* (2017); [8] Morrison et al., *Am Min.* (2018); [9] Sutter et al. *JGR,* (2017); [10] Sklute et al., *JGR,* (2015); [11] Vaniman et al., *Nature,* (2004); [12] Wang et al., *GCA,* (2006), [13] Wang and Zhou, *ICARUS,* (2014); [14] Wang et al., *JGR,* (2012); [15] Sklute et al., *ICARUS,* (2018); [16] Morris et al., *LPSC,* (2015); [17] Toner et al., *Icarus,(* 2014); [18] Wang et al., *ICARUS,* (2019); [19] Sobron and Wang, *JRS,* (2012); [20] Wu et al., *EPSL,* (2018); [21] Wang et al., *9th Mars #6117,* (2019); [22] Yan and Wang, *this volume,* (2020); [23] Wang et al., *JGR,* (2011).