# ❷ Extraction Processes in Supercritical Fluids (SCFs)

- observations from recent work by Debelak at Vanderbilt University on the use of surfactants to enhance the extraction of metals in supercritical carbon dioxide from feedstock resembling compounds found in Martian soil

# Pressure-dependent solubility in SCFs

- in the SC regime, solubility strongly affected by pressure

☞ good for extraction

- few studies of SCFs in extractive metallurgy

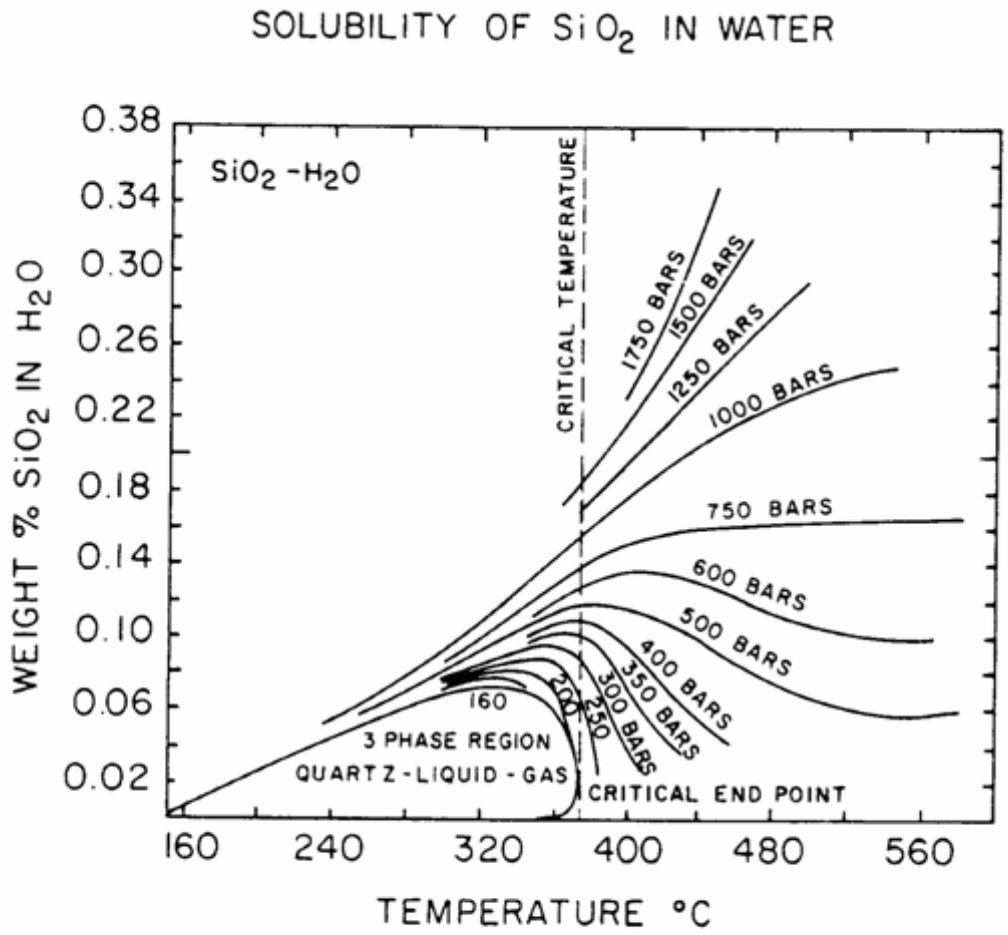



**Figure** 1 Solubility behavior of solid silica in supercritical water (Kennedy, 1950).

# ❷ Huge gaps in the database

- solubility data known for many organic compounds
  - solubility criteria have been specified
- solubility data for inorganic compounds spotty
  - solubility criteria are unknown

# ❷ Enhancing solubility of inorganics in SCFs

Debelak proposes the use of a nanoemulsion of water in $CO_2$ to compensate for the absence of dipole moment and low dielectric constant of $CO_2$

very small amounts of water are required (~0.2%)

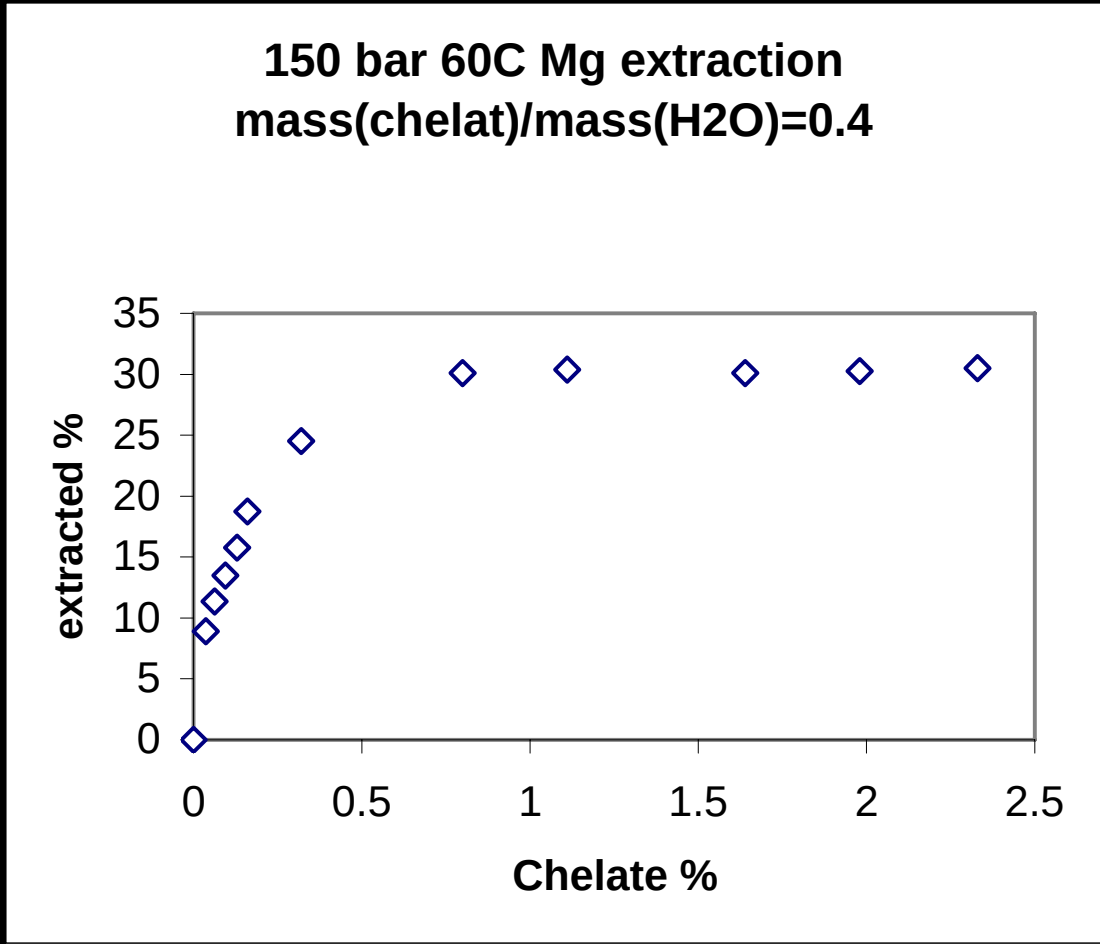
the nanoemulsion is stabilized by the use of a surfactant such as perfluoropolyether

dramatic increases in solubility have been measured with magnesium and copper compounds

# ❷ Enhancing solubility of inorganics in SCFs

0.5% chelate with
0.15% water raise
extraction efficiency of
magnesium to 30%

effect of particle size
under study



# ❸ Electrolytic Extraction in Molten Regolith

- observations from recent work by Sadoway at MIT on the extraction of metals and the production of oxygen by electrolysis of molten regolith

# Why molten oxide electrolysis?

most metals are found in nature as oxides

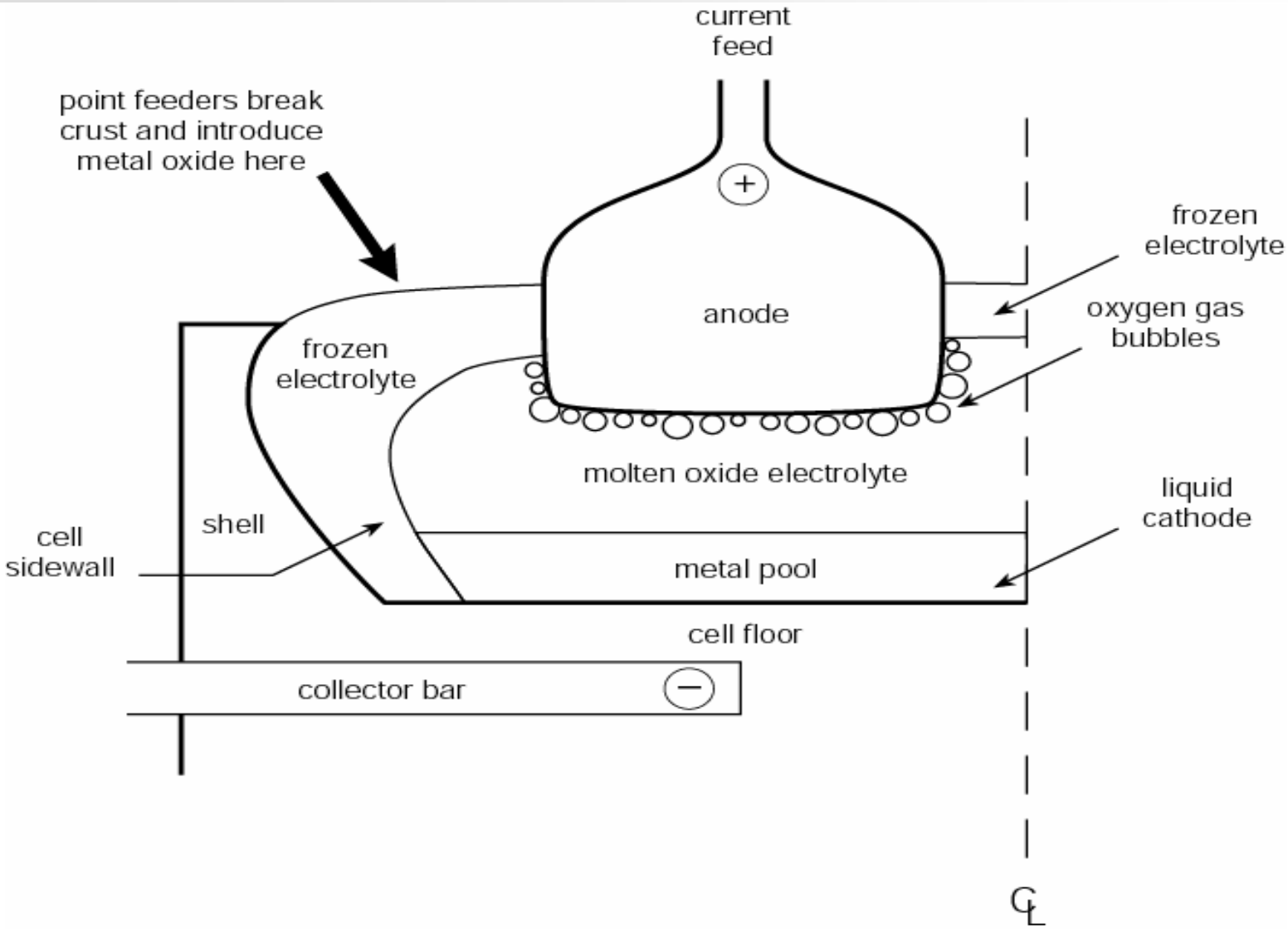
"like dissolves like"

☞ molten oxide electrolysis:

extreme form of molten salt electrolysis

where pure oxygen gas is by-product

# Prototype electrolysis cell: schematic



# Simulant properties critical to electrolysis

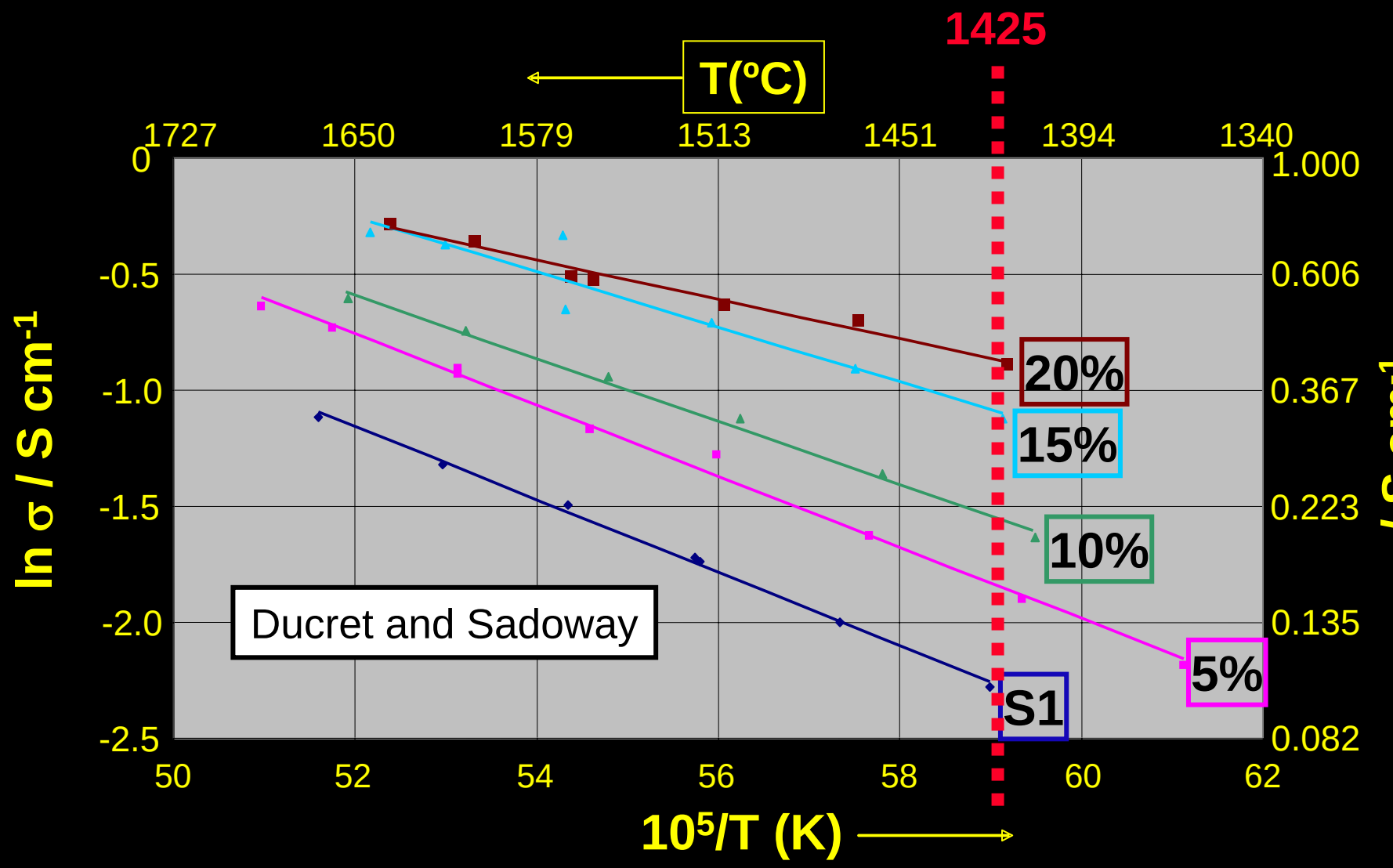
- in molten oxide electrolysis, the solid state properties of the simulant, e.g., particle size, crystal structure, and porosity, take a back seat to melt behavior
  - electrical conductivity
    density
    viscosity
    surface tension
    vapor pressure

*key attributes*

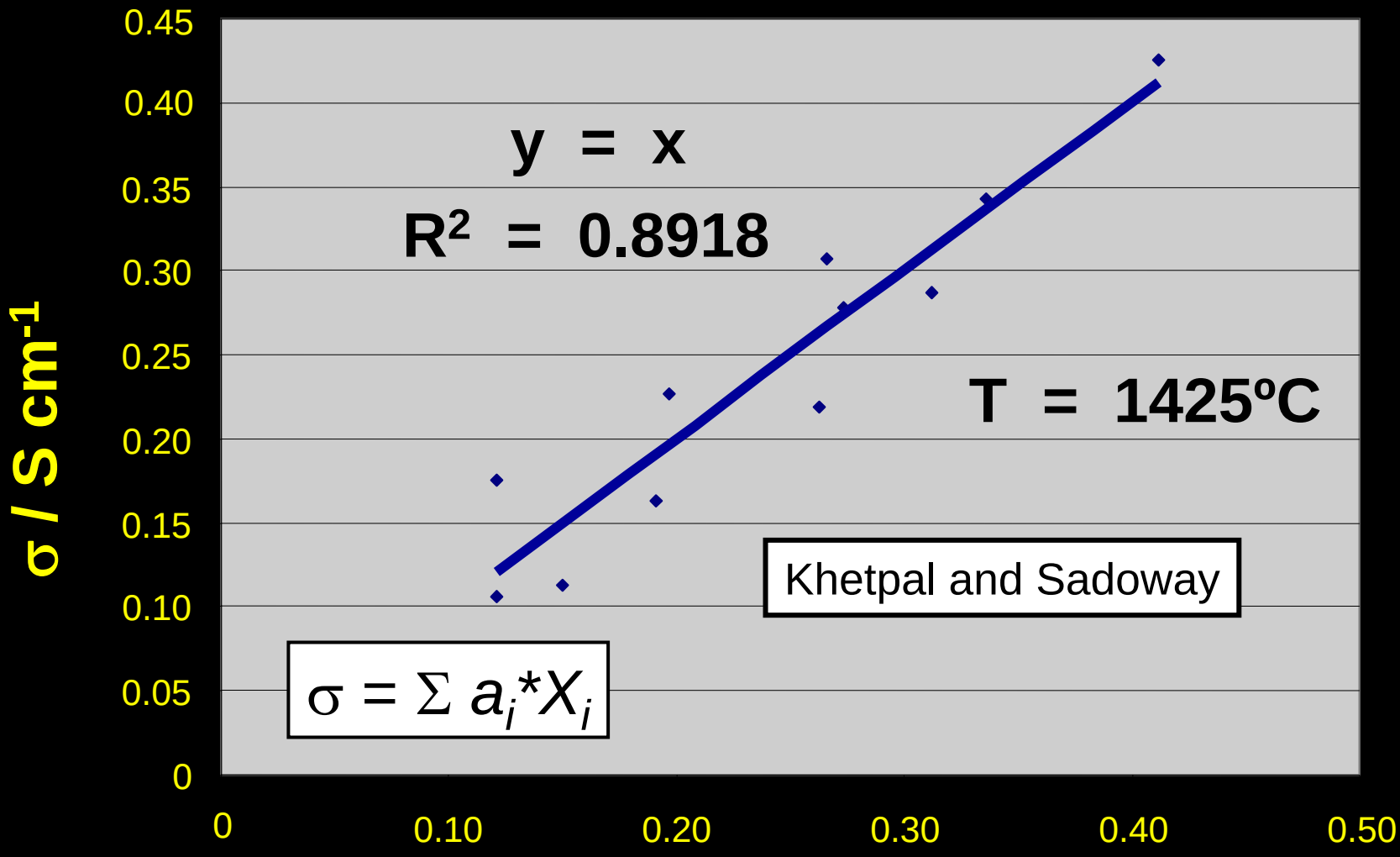
# Electrical property measurements

- studies of the FeO – MgO – CaO – $SiO_2$ system demonstrate the complex interplay of ionic and electronic conductivities which have a huge impact on process viability
- database is sparse and we are far from developing deterministic models of transport properties of oxide melts

# Effect of FeO concentration on conductivity



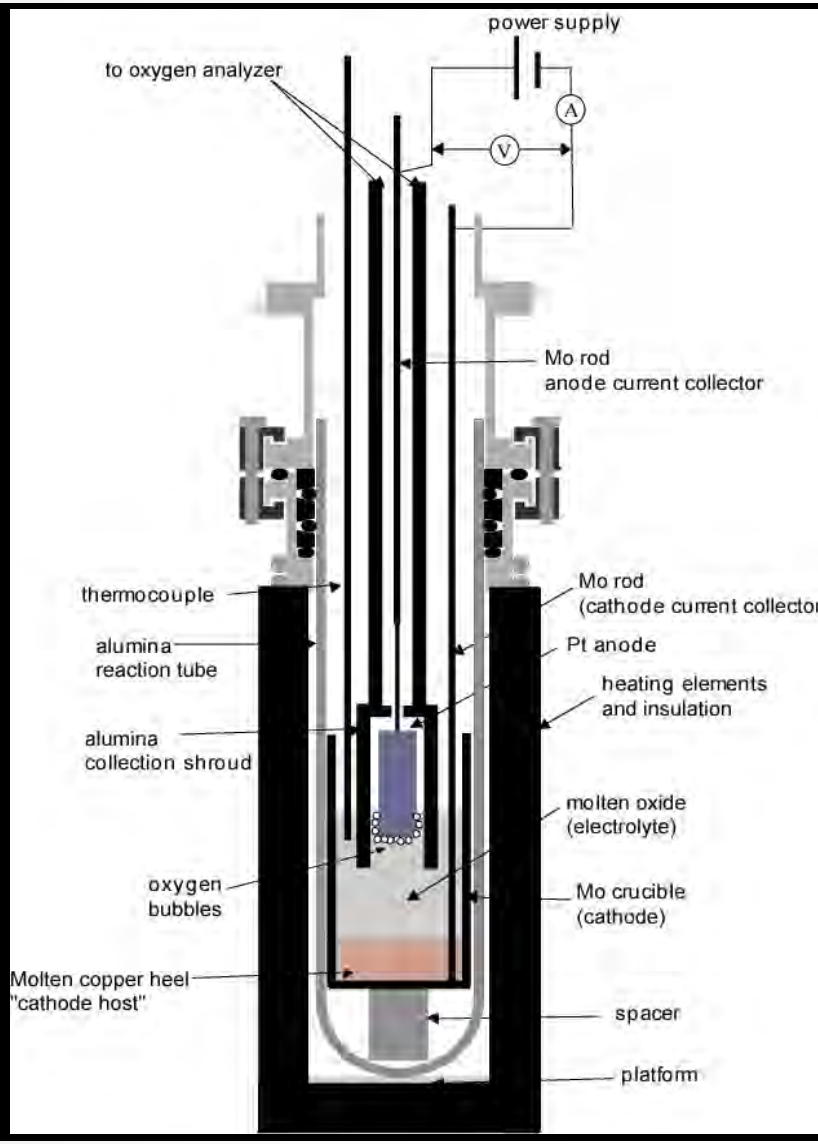
# Isothermal regression of composition




$\sigma = -0.138 - 0.361*SiO_2 + 1.186*FeO + 0.917*(FeO+MgO+CaO)$

# Laboratory-scale electrolysis cell

- towards electrolytic extraction of structural metals (Fe, Ti), photovoltaics (Si), and propellants ($O_2$)
- oxygen production demonstrated in laboratory cells



# … In summary

- one size does not fit all: different extraction processes are sensitive to different simulant properties
- is it time for a greater role for computational materials science, i.e., how good are state-of-the-art models of thermodynamic and transport properties of lunar regolith?