Overview of SAGD Operations: Gas, Solvents And Water

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Background: Source of Gases in SAGD

- Aquathermolysis
- A term coined by Hyne et. al. at the University of Calgary.
- Denotes a Solvolysis (a reaction of bitumen substrate with the solvent).
- The solvent is Aqueous (steam condensate).
- High Temperature.
- Understood in terms of normal organic chemistry.

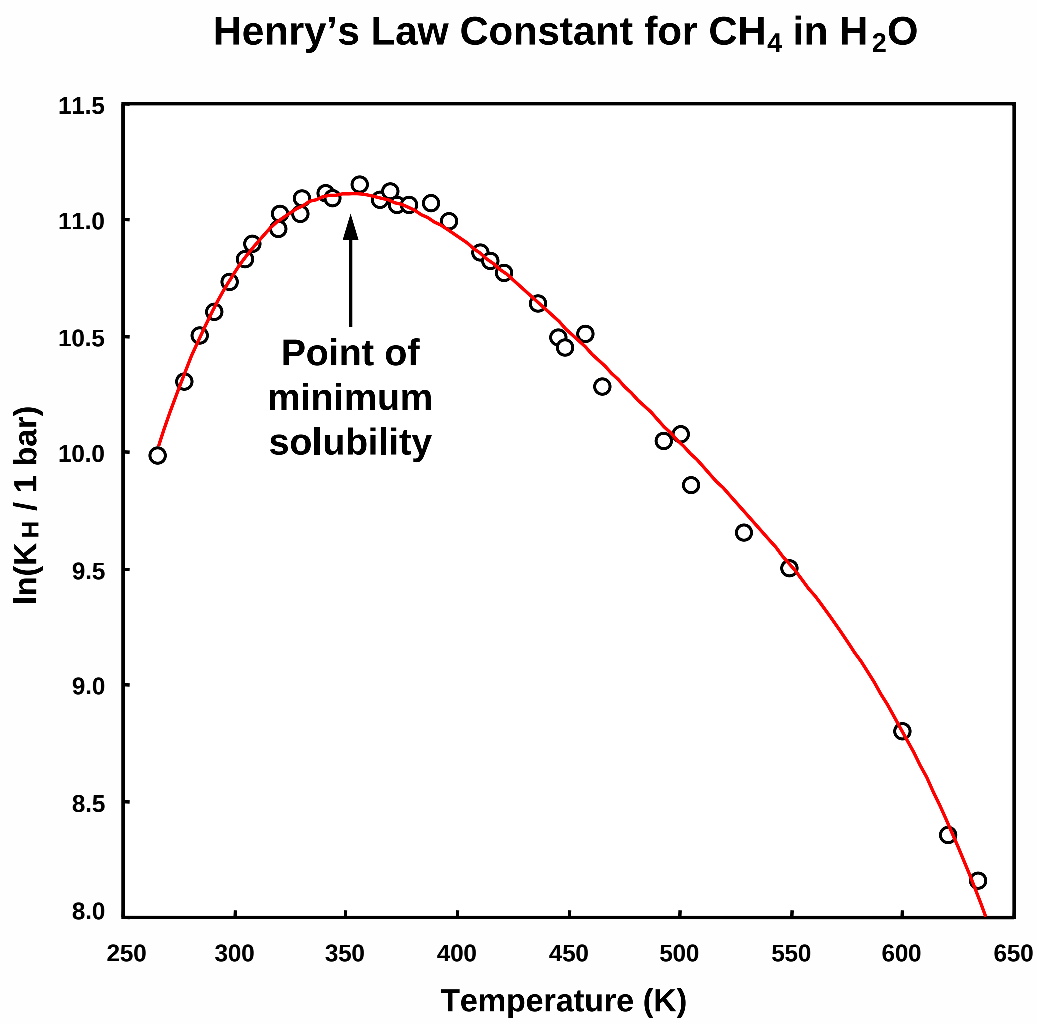
Background: Source of Gases in SAGD

- Aquathermolysis is the source of a number of gases found in SAGD production, among them:
  - Hydrogen Sulphide
  - Carbon Dioxide
  - Minor amounts of methane (can often be ignored).
- Most methane production is due to solution gas.

Background: Source of Gases in SAGD

- **Partitioning of aquathermolysis and solution gas methane in the steam zone.**
- **There are three phases:**
  - **Bitumen**
  - **Water**
  - **Gas Phase (or steam phase).**
- **Complicated by unusual solubility of gases in water at high temperature and pressure.**

Henry's Law Constant for Methane in Water



At high temperature, solubility increases dramatically.

Henry's Law

- **Asymptotic behavior of gas solubility near the critical point of water (374ºC).**

$$K_D = y/x$$

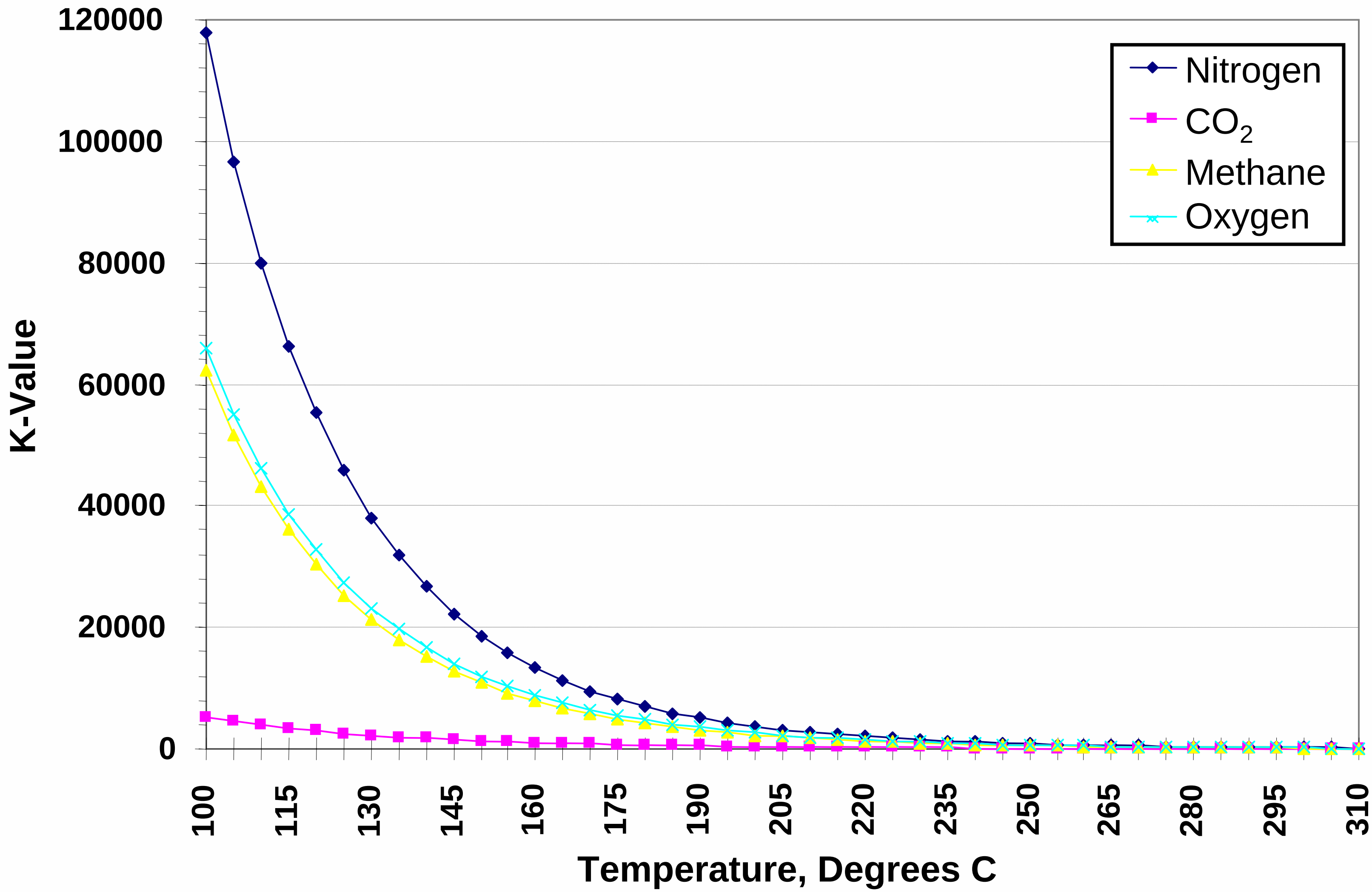
- **Harvey, Levelt Sengers , Japas , (1990's).**

$$RT \ln (K_D) \text{ linear with } (\rho_L - \rho_C)$$

$$\text{and approaches zero at } T_C$$

All gases increase in solubility in water at SAGD temperatures, as KD approaches unity.

K-Values for Selected Gases in Water at Saturated Steam Temperatures

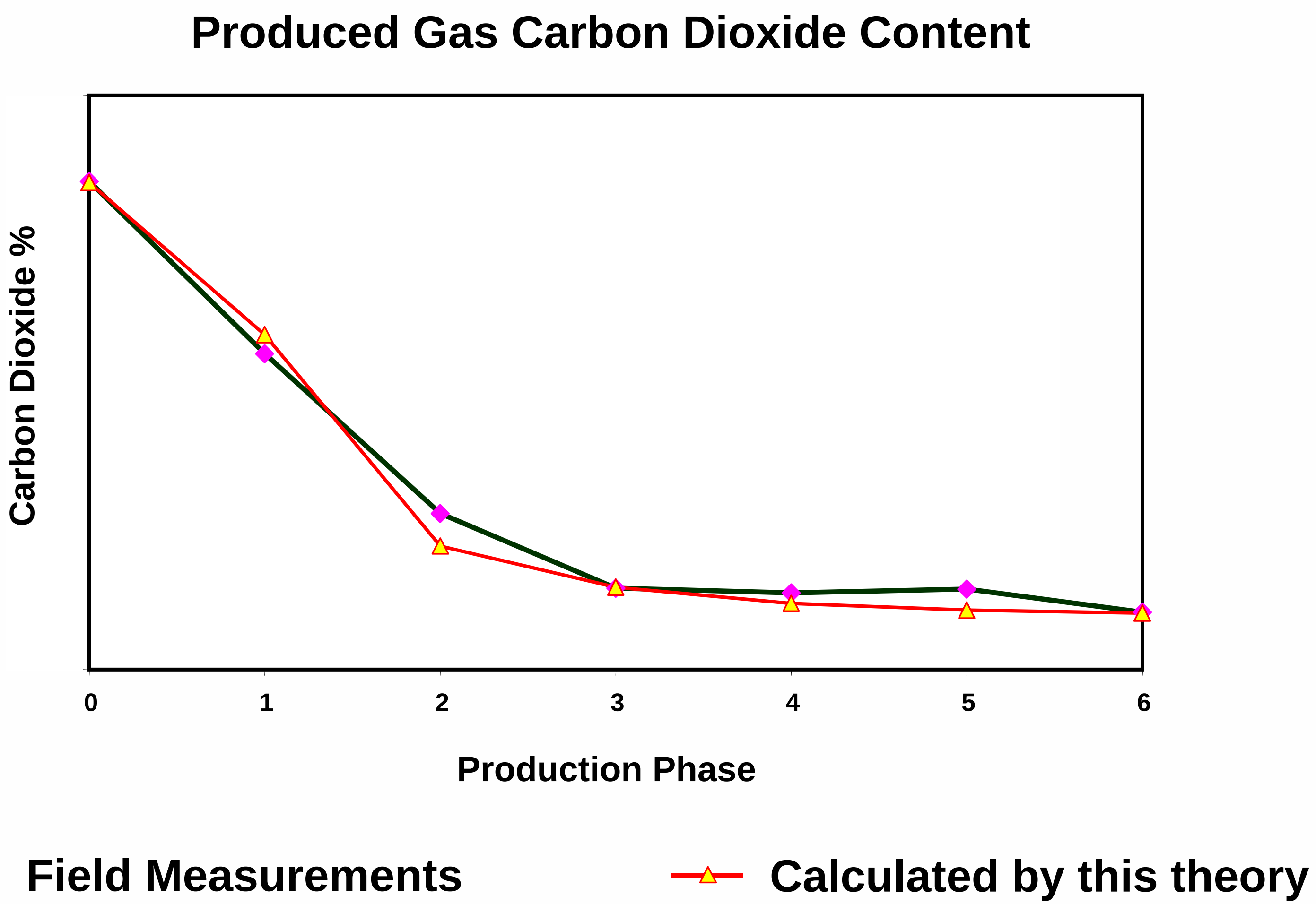


Typical Results: Field vs. Predicted

Initial Pressure 400 kPag	Initial Pressure 3000 kPag
Temperature= 208º C	Temperature = 240º C
Predicted H_2S = 21.8 L/Tonne Bitumen	Predicted H_2S = 50 L/Tonne Bitumen
Actual H_2S = 22.1 L/Tonne	Actual H_2S = 55 L/Tonne

- **Normally GOR = 1 – 16.**
- **H_2S varies from 1,000 to 30,000 ppm.**
- **Predictions (Thimm, 2001) match field results.**

Field vs. Theoretical Results



Consequences

- We have the means of calculating the concentration of carbon dioxide in the steam condensate of the SAGD steam zone.
- Carbon dioxide suppresses the solubility of quartz in the SAGD steam zone.
- In principle, we can estimate the silica production rate from theory of solution thermodynamics.

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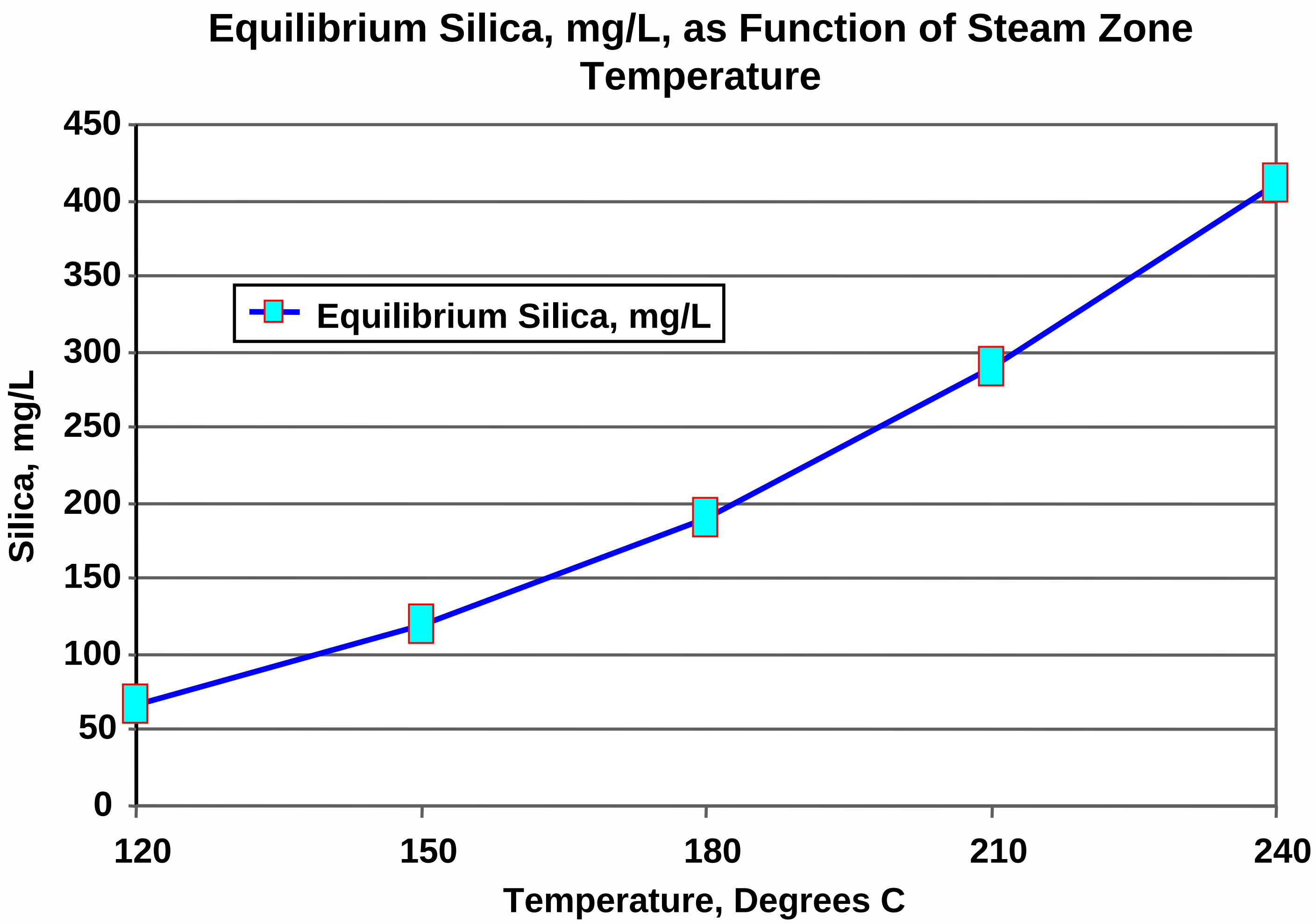
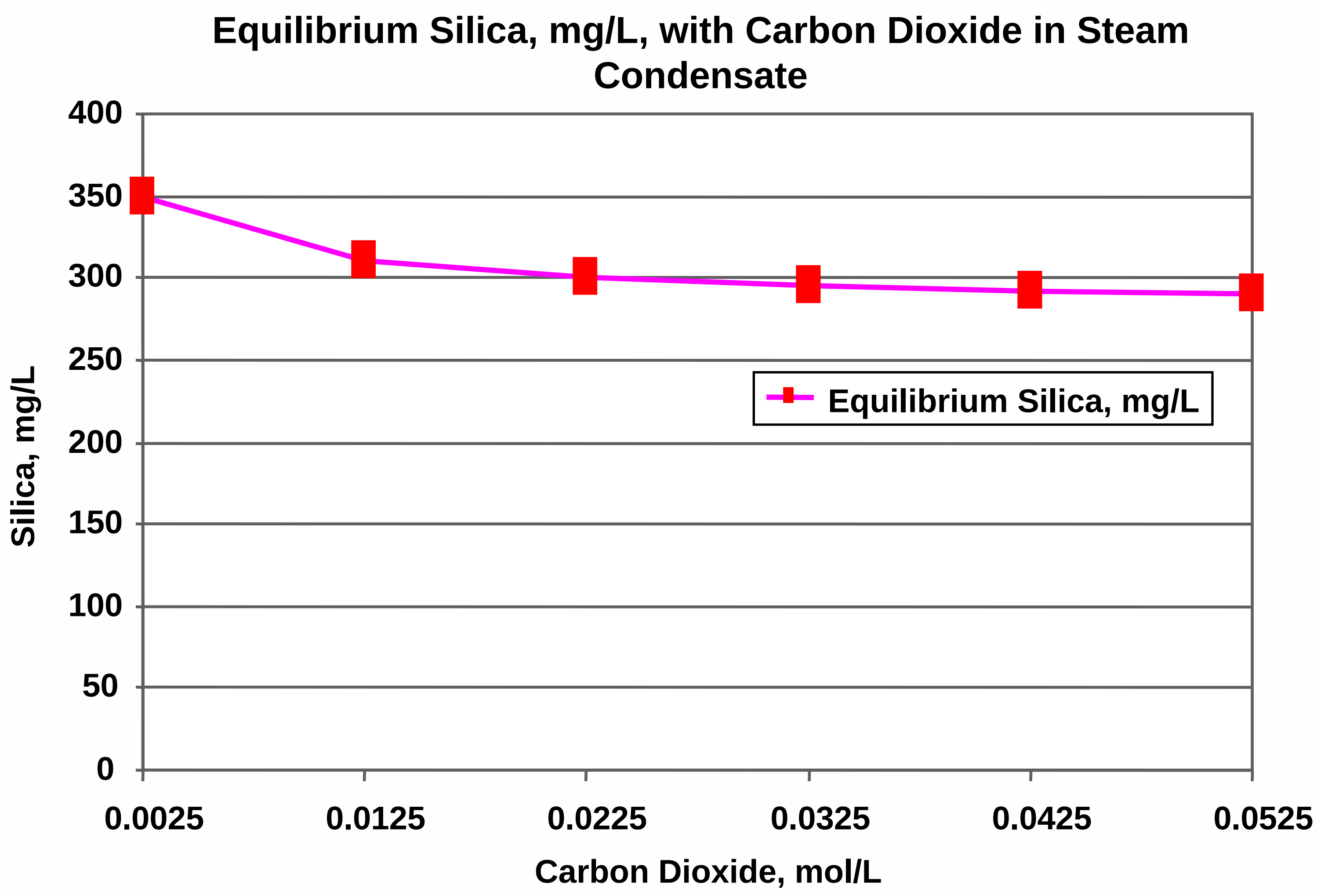
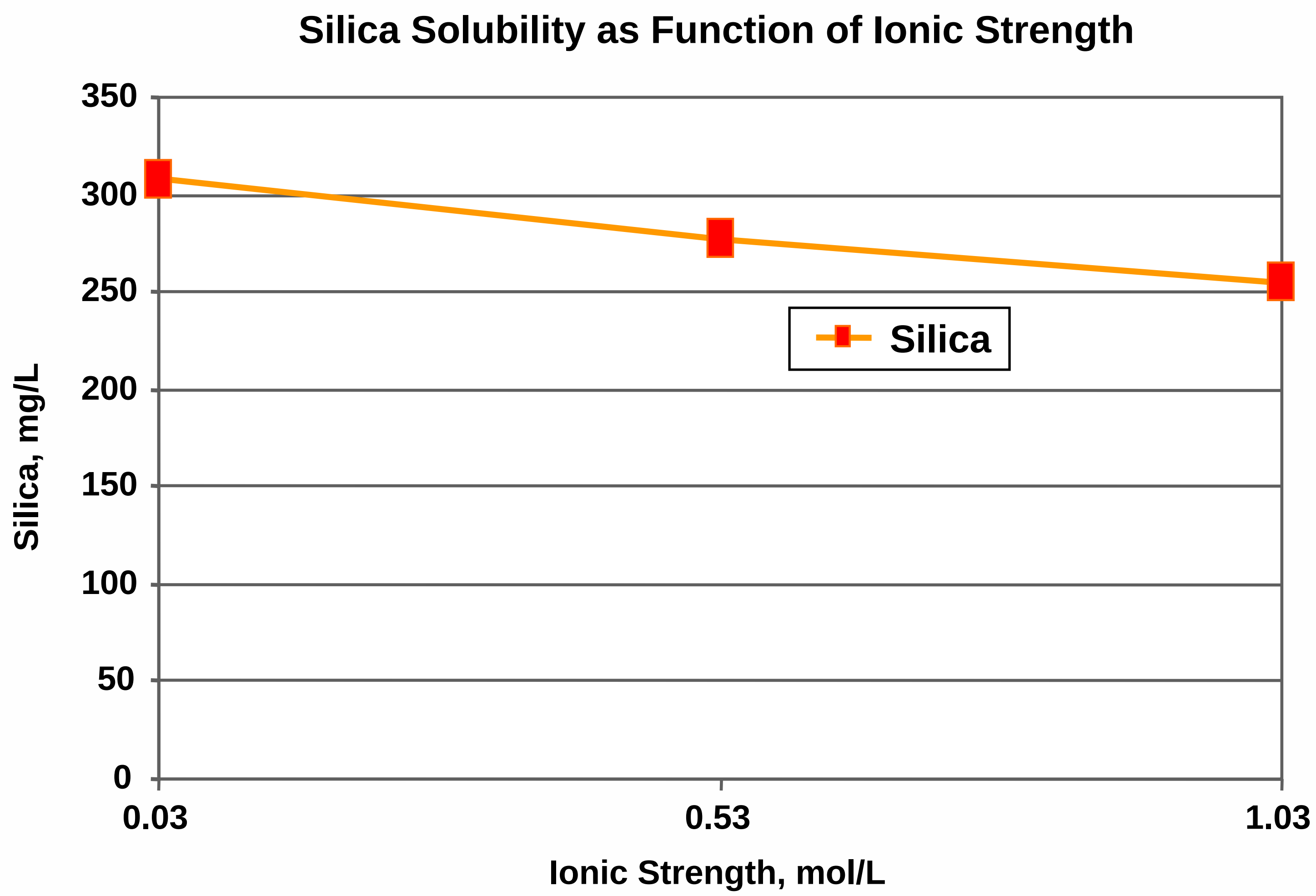
Quartz By Solmineq Simulation



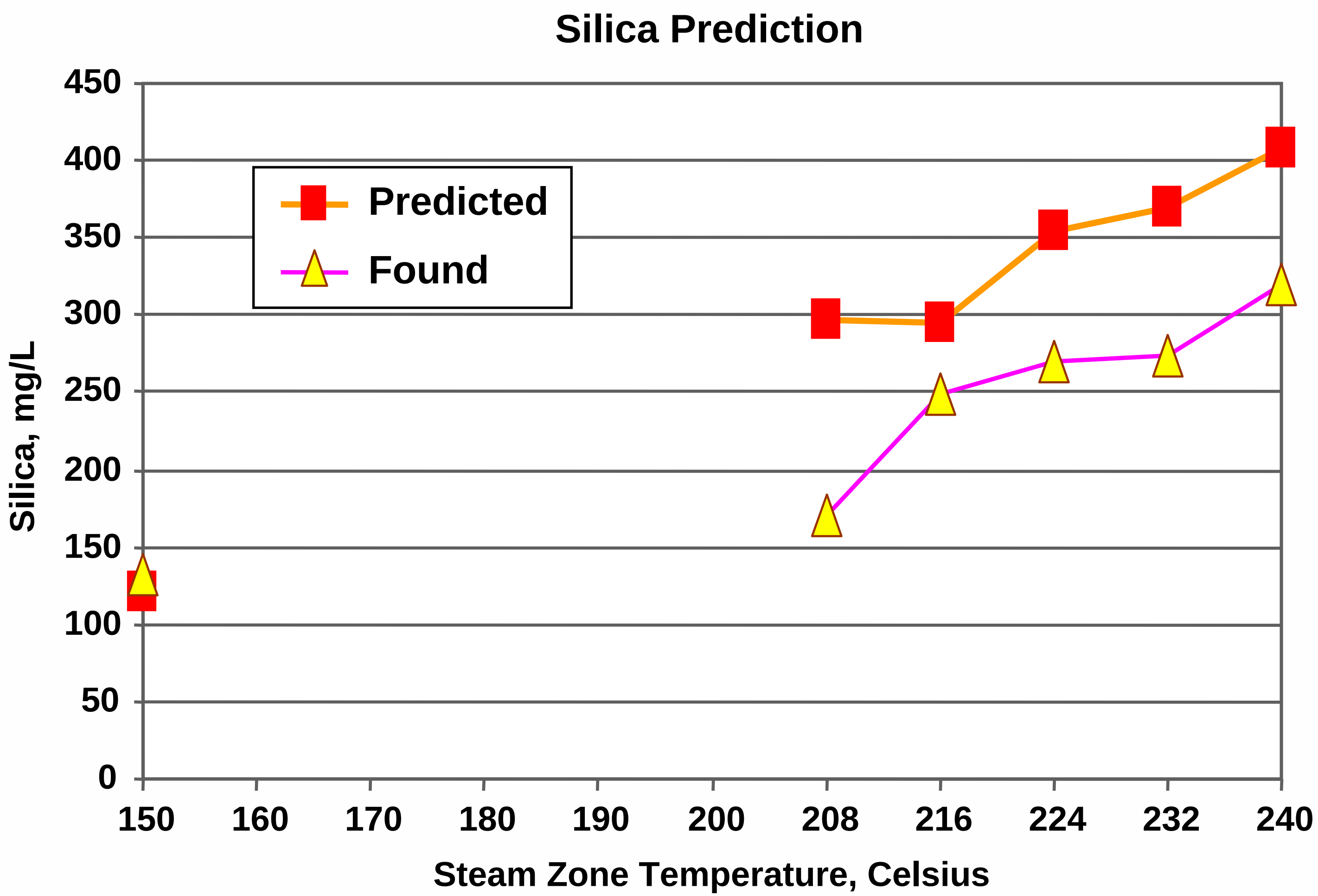
Carbon Dioxide Effect



Ionic Strength Effect



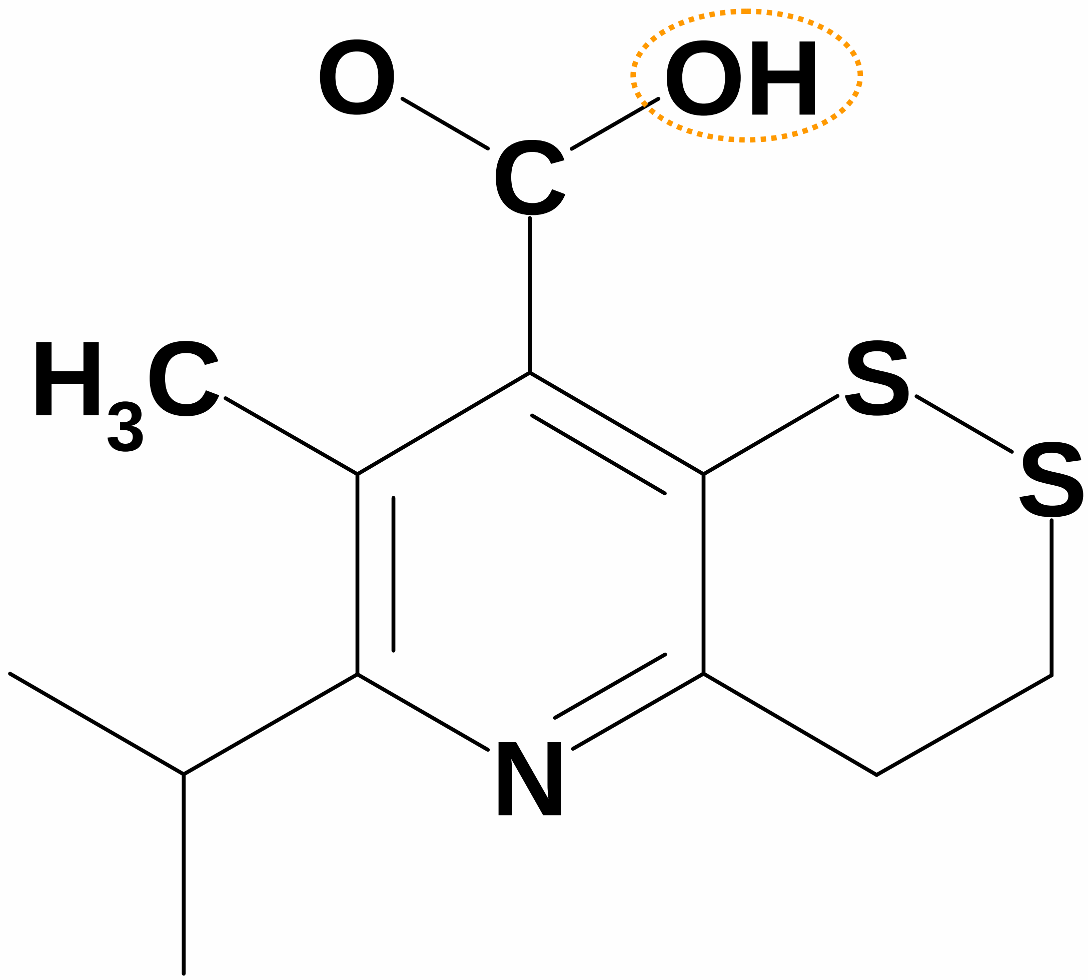
Combination of Effects: Field Vs. Theory



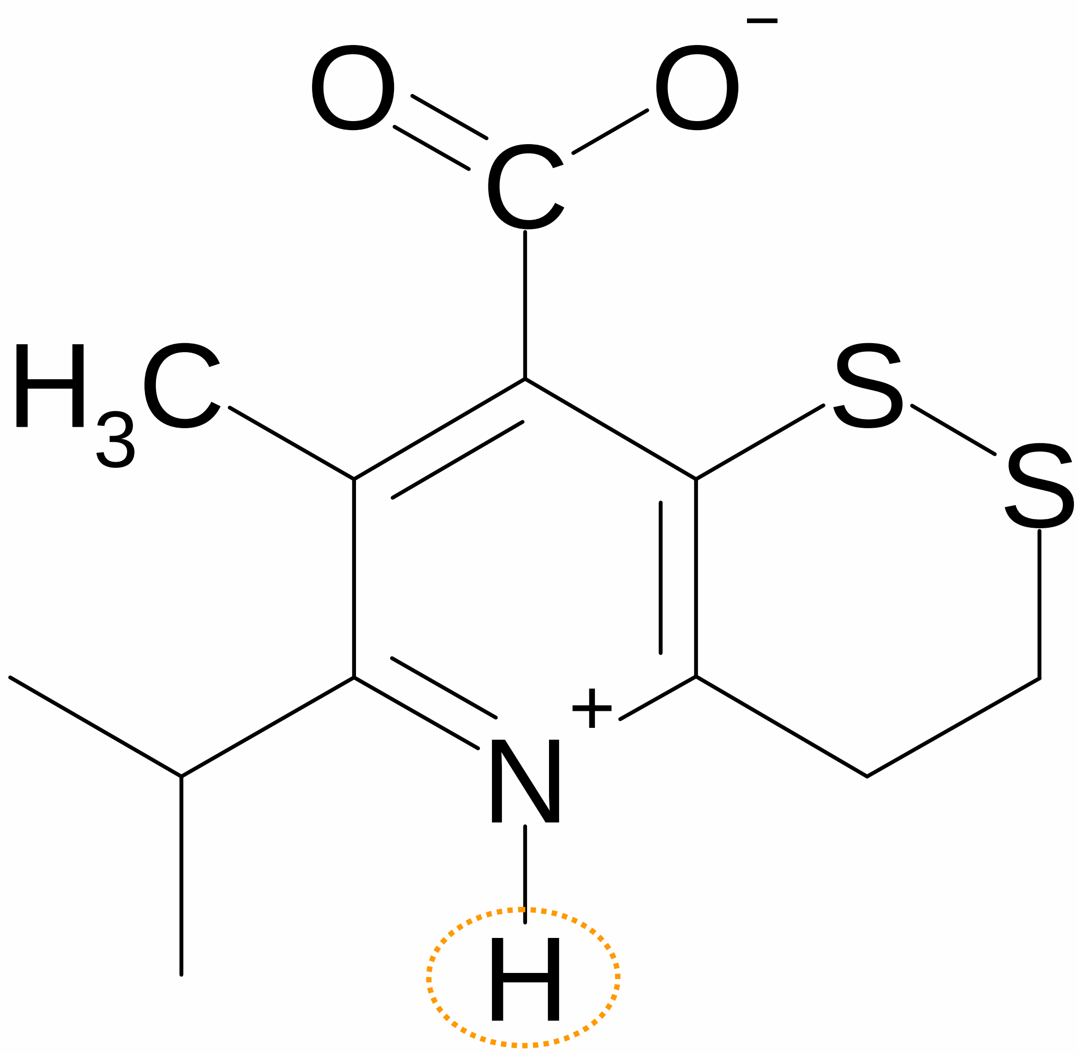
Method of Silica Analysis

- **Method of silica analysis appears to be important to account for 25% deviation.**
- **Poorest agreement in 2 cases where reactive silica analysis by colourimetric methods is involved. So-called "reactive silica" analysis.**
- **Other methods involve ICP analysis, but the time delay and crystallization during transport and analysis are an issue.**

Organic Derived from Bitumen



Found as Precipitate with Ca^{2+} and Sio_3^{2-}



Consequences

- The solution thermodynamics also apply to various hydrocarbon solvents.
- This allows predictions of:
  - Optimal solvent composition choice for solvent co-injection.
  - Prediction of retention of solvent components in the reservoir.
- Theory predicts reduction of hydrogen sulphide production per bbl of bitumen.

Plyasunov & Shock, 2003

- **Extension of theory to higher hydrocarbons.**

$$RT\ln K = 2A_{Kr}(\rho_L - \rho_C)/\rho_C^2$$

A_{Kr} = Krichevskii Parameter (MPa).

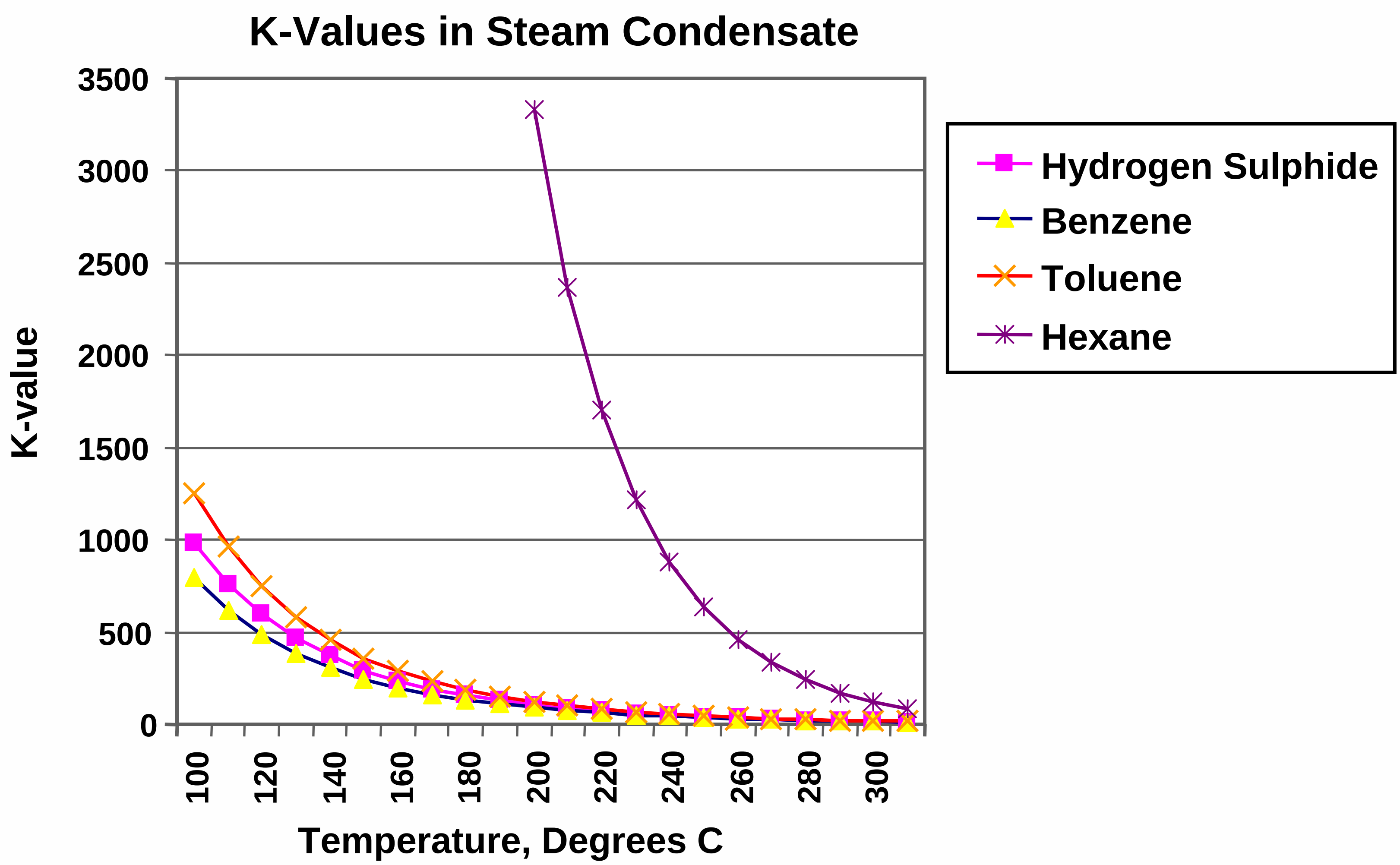
ρ_L = Density of water.

ρ_C = Density of water at critical point.

Some Krichevskii Parameters

Carbon dioxide	121.7 MPa
Hydrogen sulphide	96.6 MPa
Methane	162.6 MPa
Ethane	162.9 MPa
Hexane	169.0 MPa
Octane	178.4 MPa
Benzene	93.6 MPa
Toluene	100.0 MPa

K-Values in Water at Saturated Steam Temperatures



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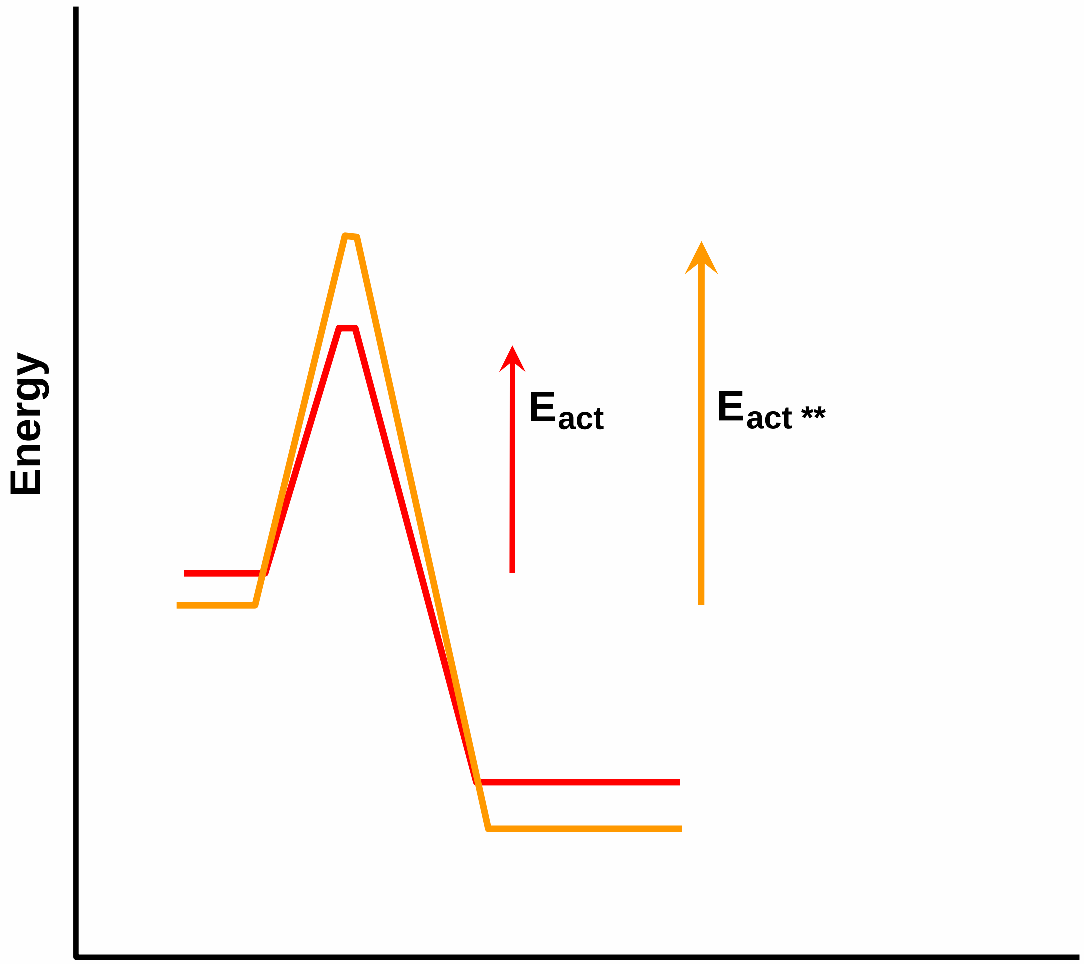
Activation Energy for Solvolysis

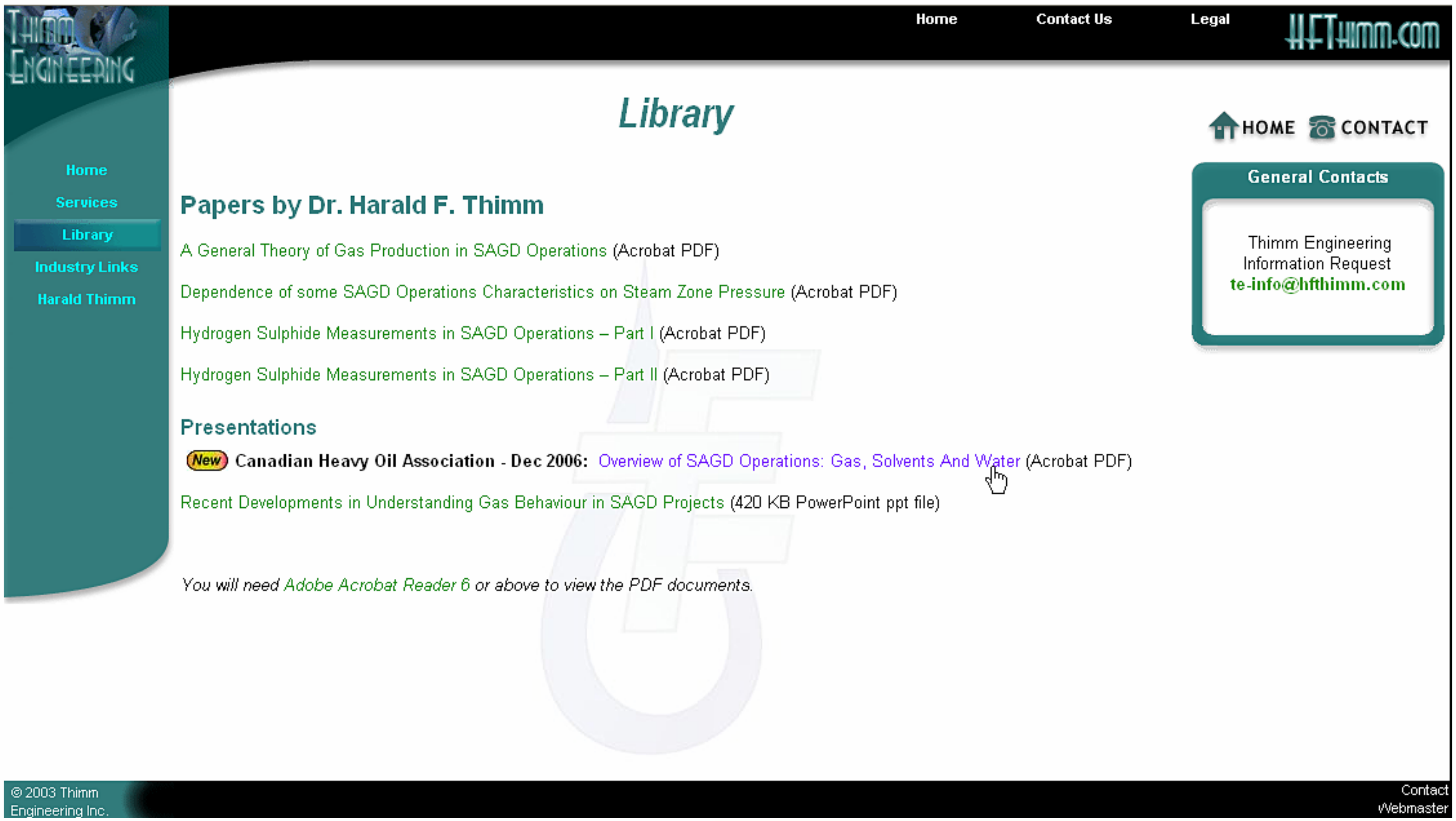


Consequences

- **Production of hydrogen sulphide should decline if the Hyne mechanism for aquathermolysis is correct.**
- **Initial results show this is so, but replication is needed.**
- **This theory is not yet on a quantitative basis.**
- **Expect a reduction of about 1 order of magnitude on the basis of initial results, enough to eliminate need for a sulphur recovery plant in some operations.**

Thimm Engineering Website

- **Download publications and presentations at *www.hfthimm.com* (look in the online '*Library*')**



Acknowledgements

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