



## **Methane Hydrate Formation, Storage and Dissociation Behavior in Unconsolidated Sediments in the Presence of Environment-friendly Promoters**

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### **Methane Hydrate Formation, Storage and Dissociation Behavior in Unconsolidated Sediments in the Presence of Environment-friendly Promoters**

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Technical University of Denmark

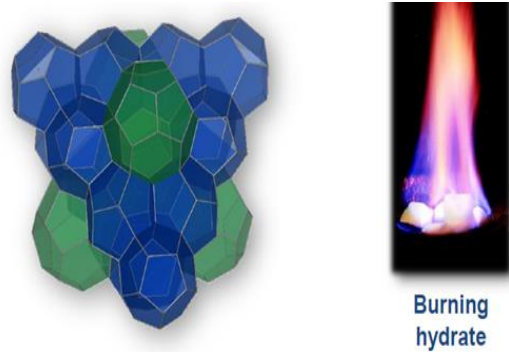
# Presentation Outline

- Introduction
- Objective
- Experimental setup
- Experimental results
- Conclusion

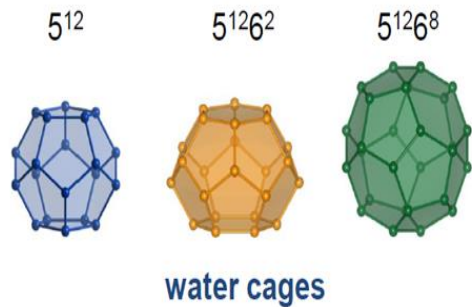
# Introduction: Gas Hydrates & Applications

- What Are Gas Hydrates

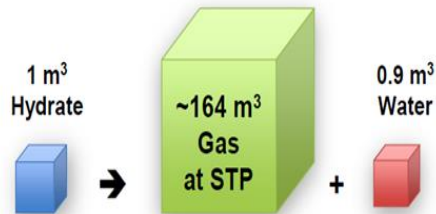
- Ice-like, crystalline structures
- Common hydrate formers: methane, ethane, propane, carbon dioxide, hydrogen sulfide, nitrogen, hydrogen



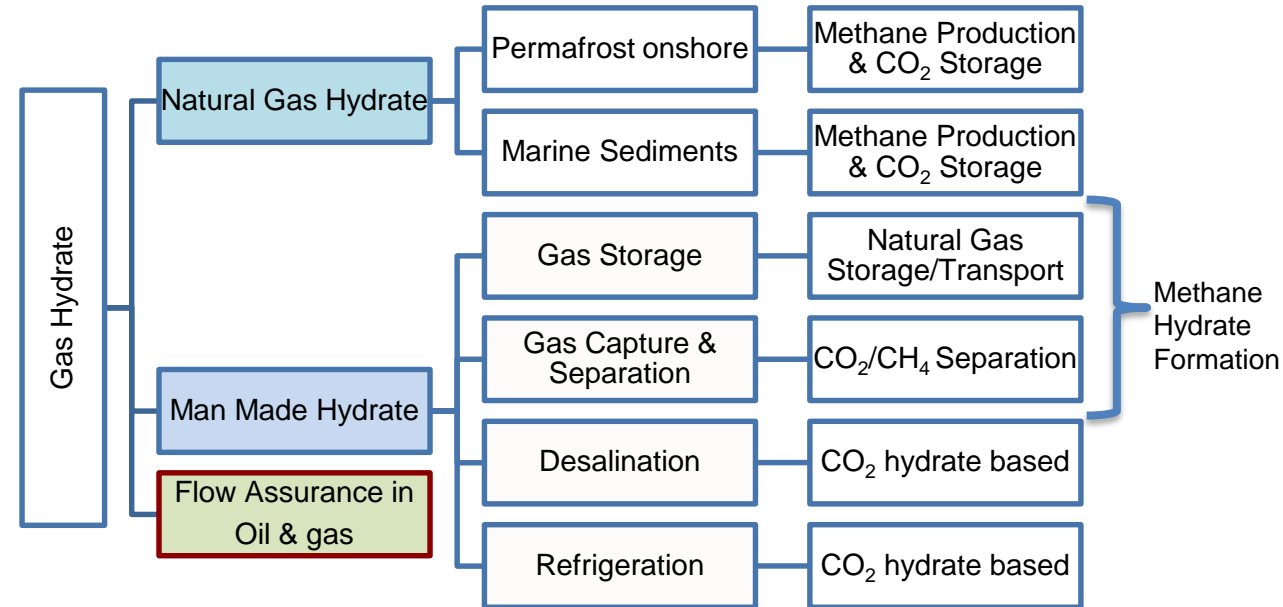
Burning hydrate



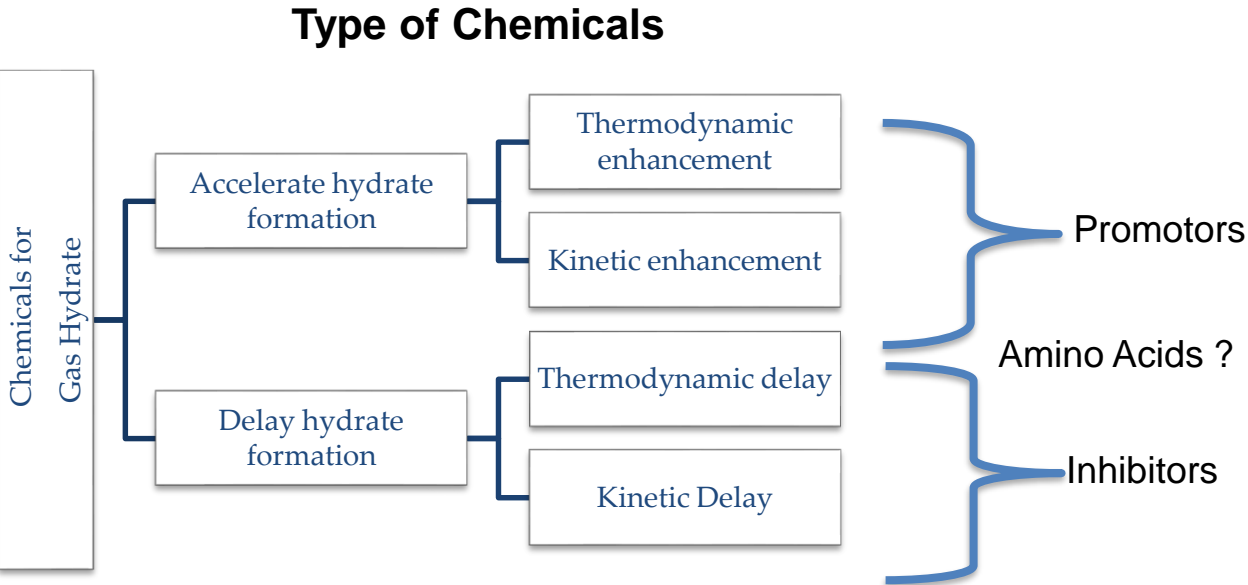
Gas storage capacity in hydrates



- Applications



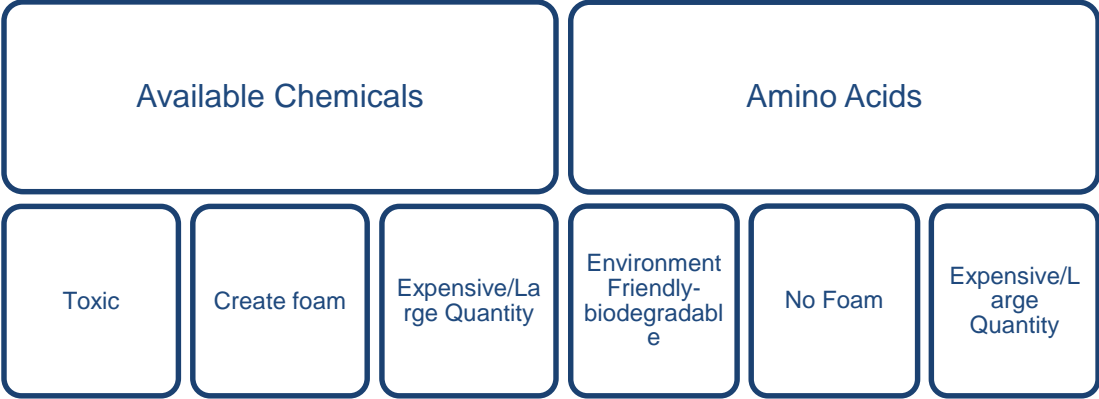
# Introduction: Role of Chemicals in Gas Hydrates



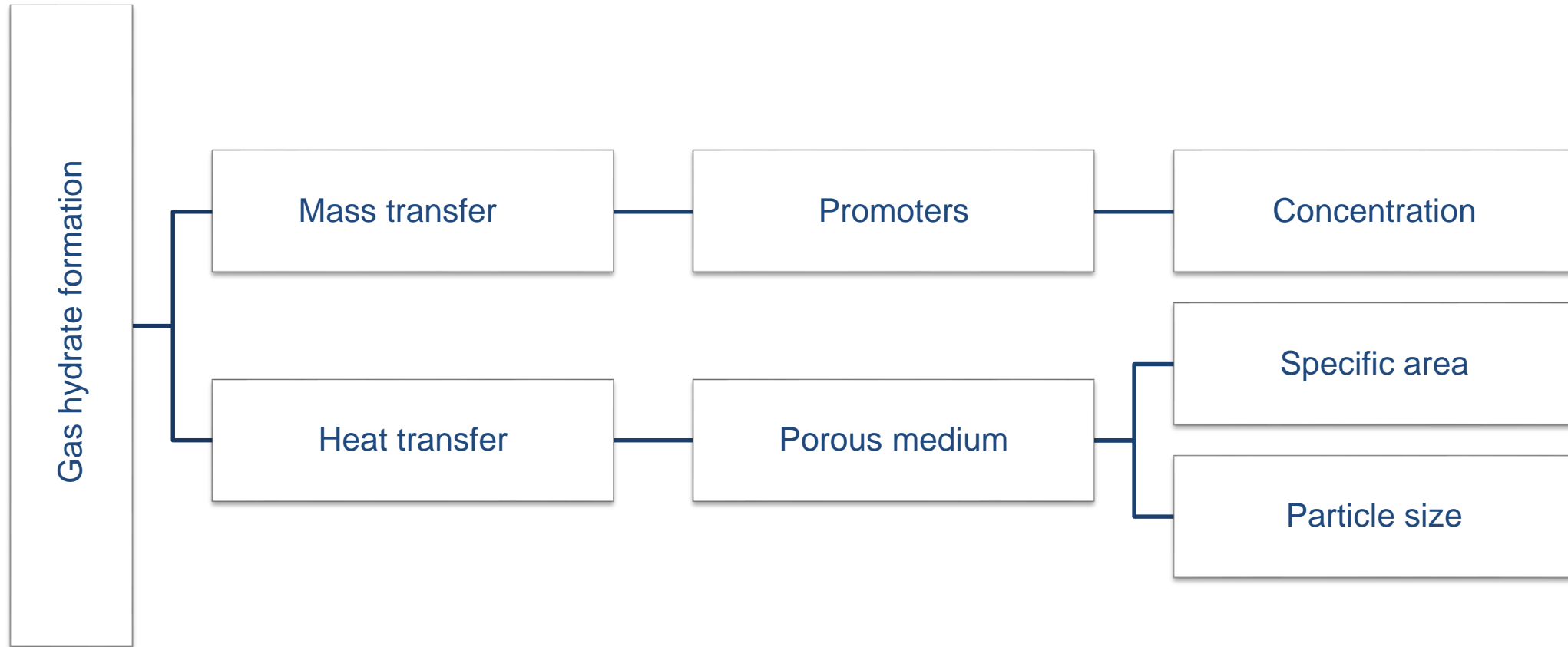
Chemicals can influence

- Surface tension
- Solubility
- Gas diffusion

## Why Amino Acids ?



# Introduction Porous Media & Promoter



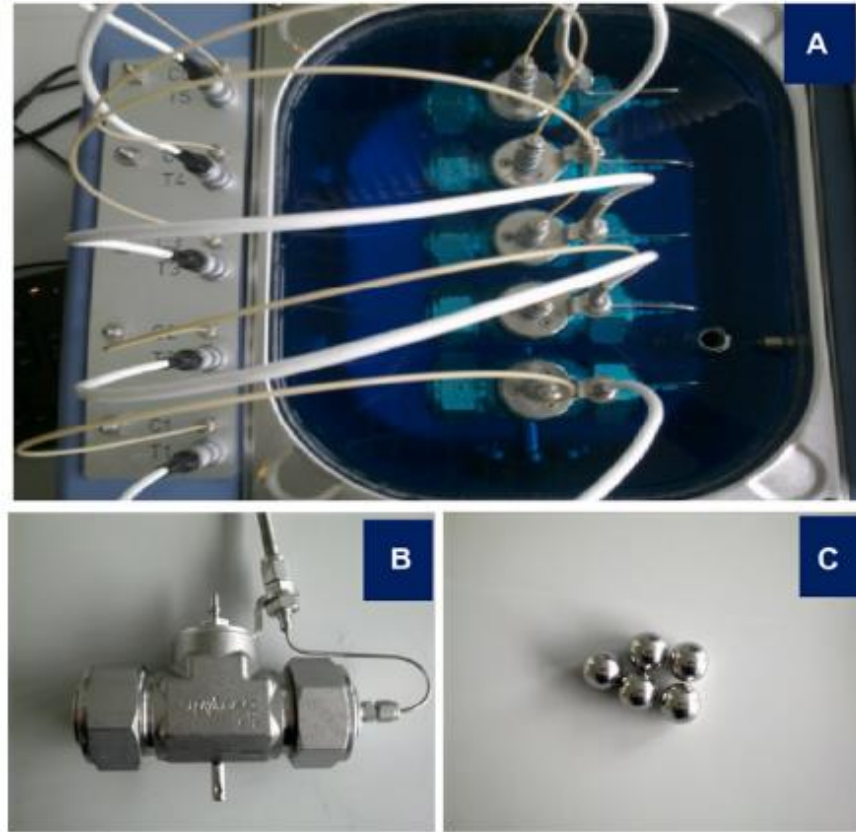
# Objective

- To study the methane hydrate formation kinetics
  - Change in particle size
  - Presence of chemicals (Amino acids & Surfactant)
- To study the dissociation kinetics

# Experimental Setup



Rocking Cell (PSL Germany)



- A- Bathtub
- B- High Pressure Cell
- C- Rocking Balls

- Rocking Rate, Rocking Angle
- Volume
- Temperature Ramping, Constant Temperature



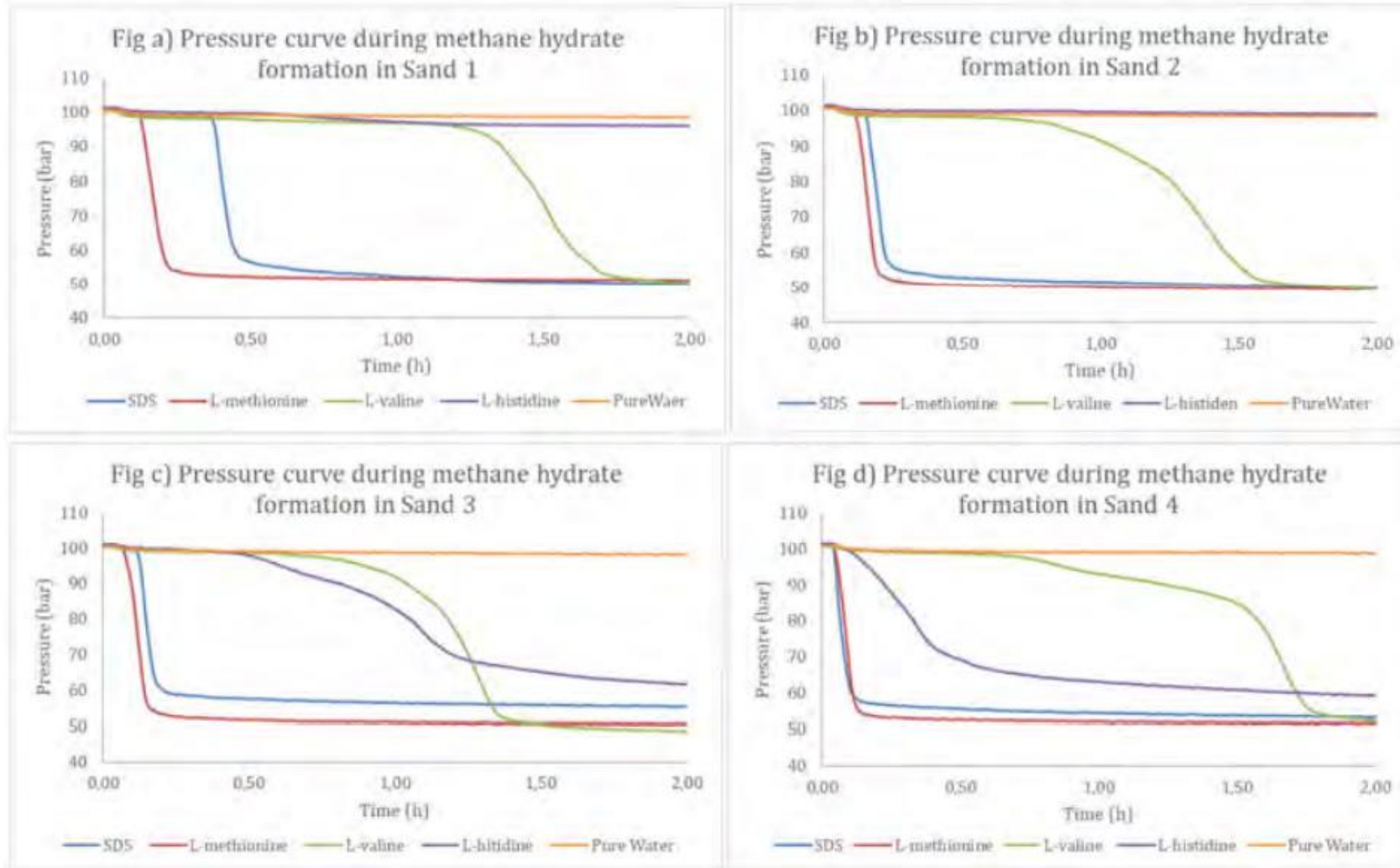
# Experimental Setup: Method and Materials

Sand	Silica Sand (4 Particle Sizes) <ul style="list-style-type: none"><li>• 46.4-245 <math>\mu\text{m}</math></li><li>• 160-630 <math>\mu\text{m}</math></li><li>• 480-1800 <math>\mu\text{m}</math></li><li>• 1400-5000 <math>\mu\text{m}</math></li></ul>
Amino acids (3000 ppm concentration)	<ul style="list-style-type: none"><li>• L-valine</li><li>• L-methionine</li><li>• L-histidine</li></ul>
Sodium dodecyl Sulfate (SDS)	500-3000 ppm (500,1000,2000,3000 ppm)
Experimental conditions	100 bar, 1°C, Isothermal experiments
Parameter calculated	Induction time, gas uptake & dissociation rate below 0°C

# Experimental Results- Formation Kinetics

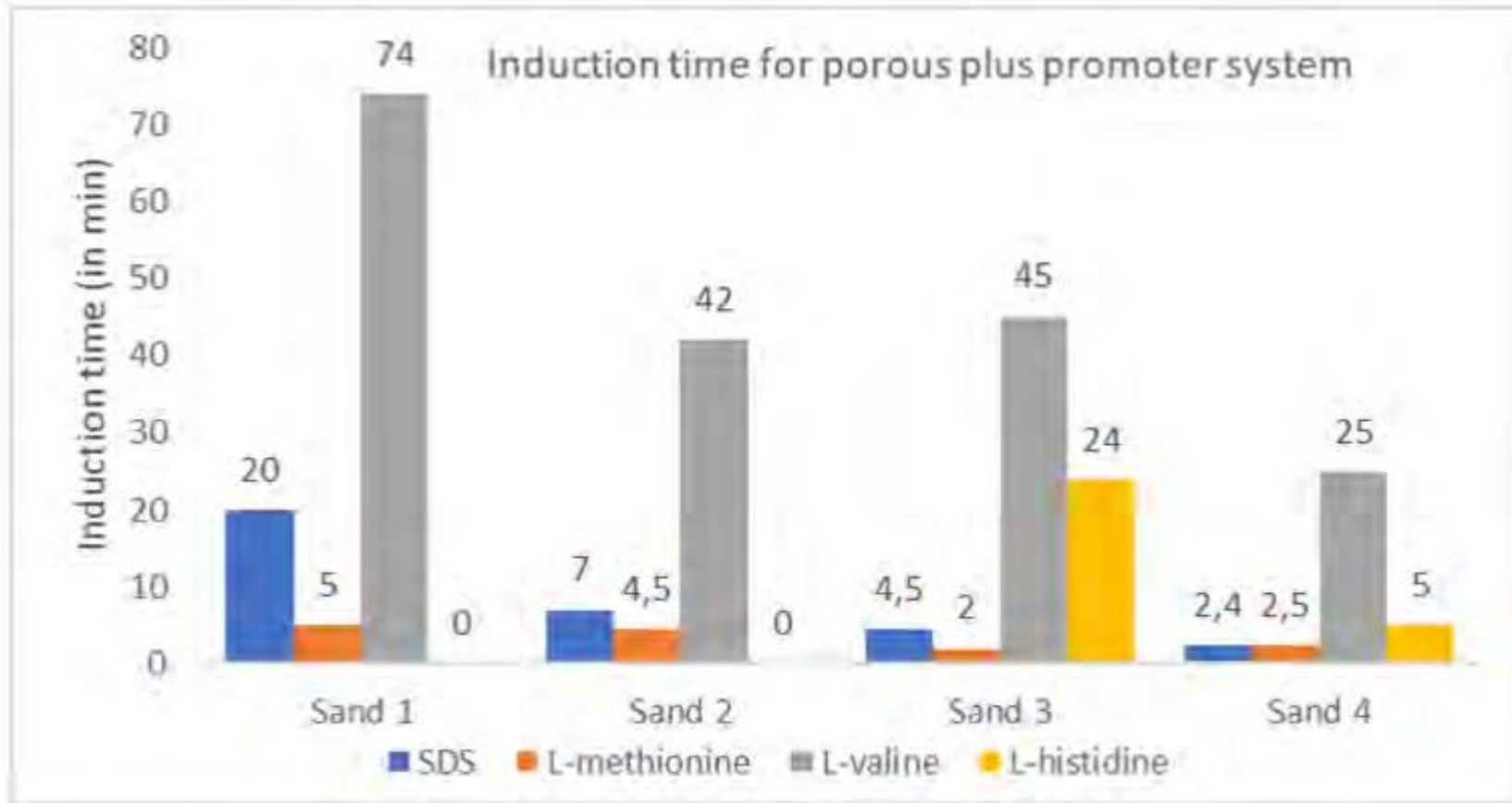
- Hydrate morphology
  - Pore filling
  - Grain coating
- Formation kinetic (Gas-liquid contact interface)
  - Grain coating – Particle surface area
  - Pore filling- Pore space
  - Large particle size: higher pore space- Large gas-liquid contact area
  - Small particle size : weak pore connectivity, barrier to mass transfer due to high capillary forces in smaller pore space
- $S_{wi} = 35\%$  change in grain coating to pore filling

# Formation-Induction time



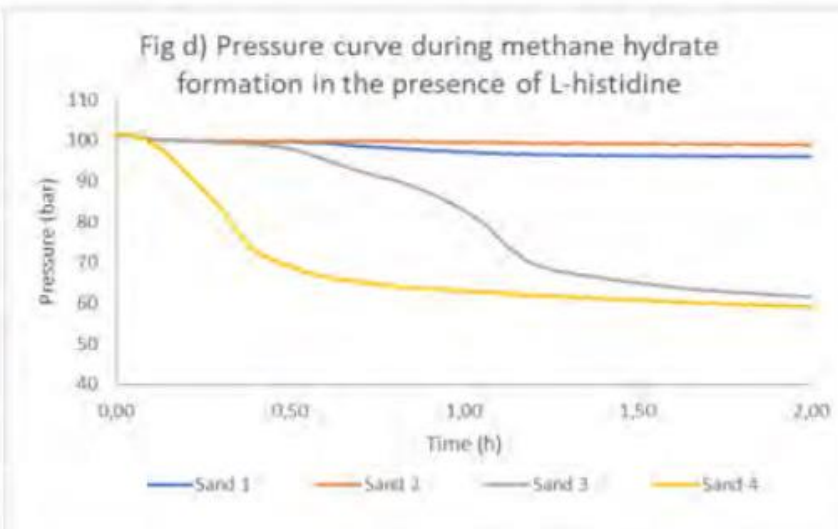
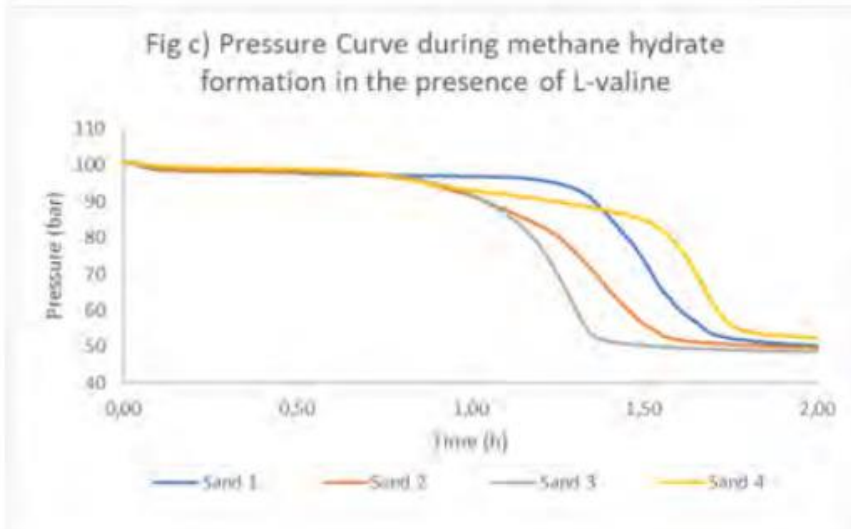
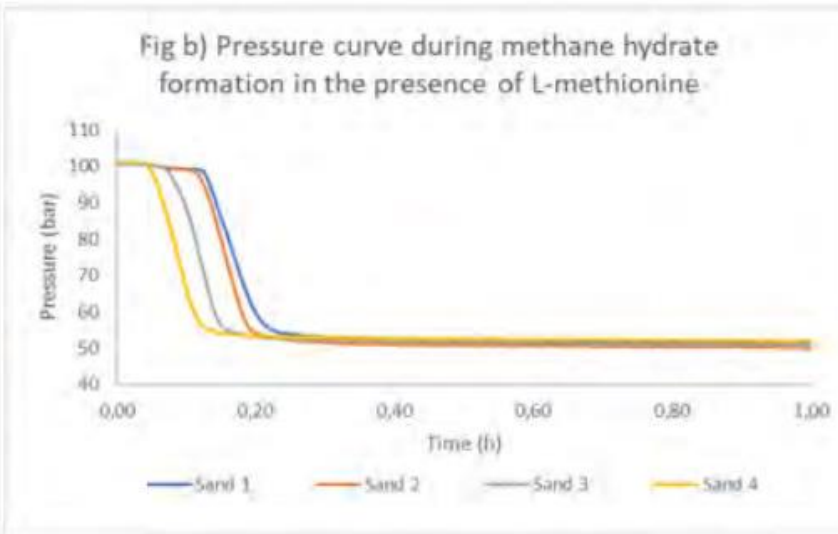
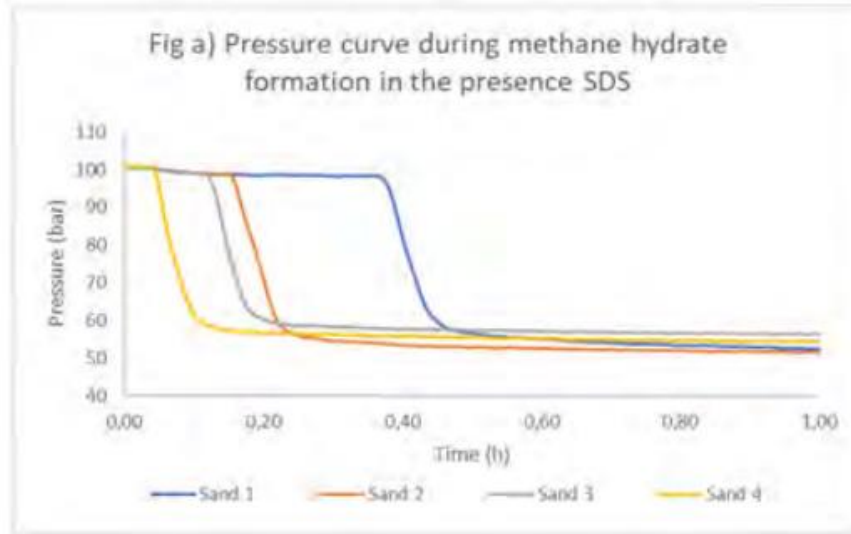
- Pressure variation during Isothermal experiments at  $P=100$  bar and  $1^{\circ}\text{C}$
- for given sand particle size
- Induction time is lower for SDS / Hydrophobic amino acids for any given particle size

# Formation-Induction time



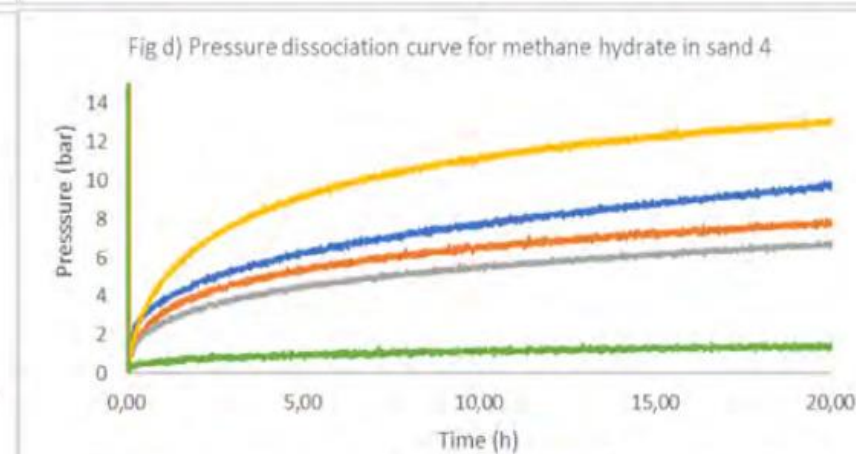
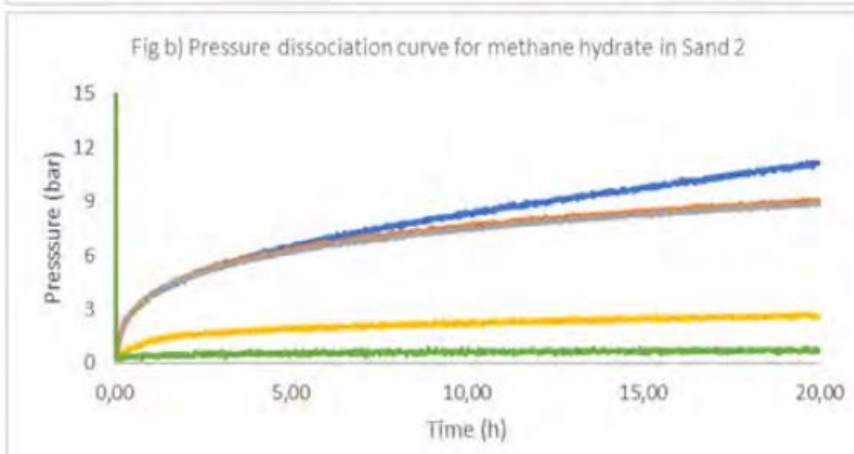
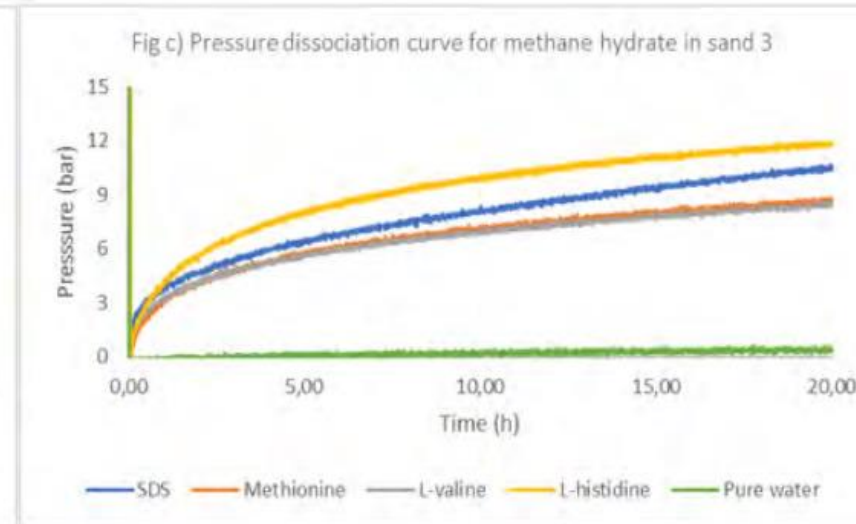
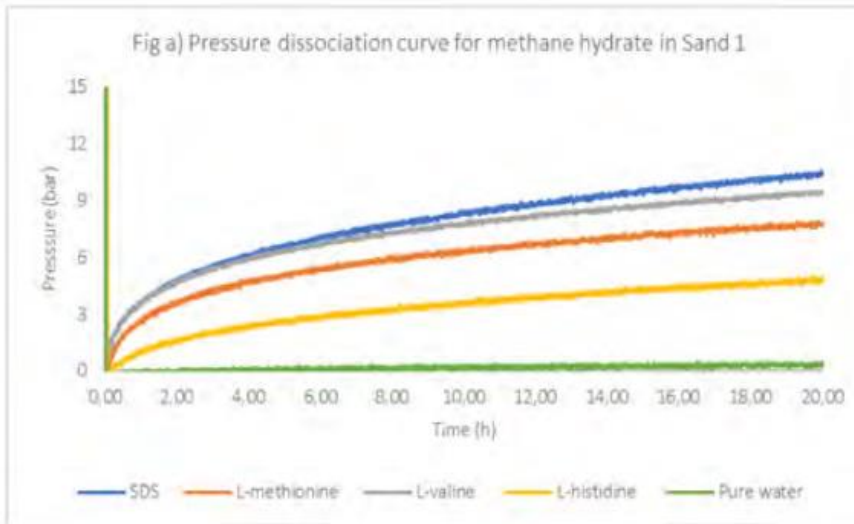
- Induction time is lower for SDS / Hydrophobic amino acids for any given particle size.
- Increase in particle size lead to decrease in induction time
- L methionine and SDS have similar induction time.
- Histidine could only formed hydrate at higher sand particle size.
- Enhanced driving force due to large gas-liquid interface

# Gas Uptake



- Pressure variation during Isothermal experiments at  $P= 100$  bar and  $1^{\circ}\text{C}$
- For low concentration (500 ppm) , increase in particle size lead to decrease in gas uptake.
- At higher concentration, effect of sand particle size reduce and role of mass transfer increase
- For large particle size, change in concentration marginally affect gas uptake.
- For smaller particle size, change in concentration had dominating effect on gas uptake

# Experimental Results-Dissociation



- Dissociation under  $T = 266.7$  K at starting pressure  $P = 1$  bar.
- Self preservation of hydrates, Surrounded by ice sheet
- Dissociation rate is dependent on initial hydrate saturation.
- SDS/Hydrophobic amino acids dissociate faster
- SDS dissociate fastest for given sand particle while amino acids dissociated slower due to enhance hydrogen bonding

# Conclusions

- $S_{wi}$  controls formation kinetics.
- Low promoter concentration, particle size effect dominates the formation kinetics dominates
- Hydrophobic amino acids have similar kinetic behavior as SDS. Less deviation between amino acids and SDS at large particle size.
- Methane hydrate self preservation in the presence of hydrophobic amino acids enhanced.

# Relevant Papers

- Pandey, J. S., Daas, Y. J., & von Solms, N. (2020). Screening of Amino Acids and Surfactant as Hydrate Promoter for CO<sub>2</sub> Capture From Flue Gas. *Processes*, 8, [124]. <https://doi.org/10.3390/pr8010124>
- Pandey, J. S., Jouljamal Daas, Y., & Solms, N. V. (2019). Insights into Kinetics of Methane Hydrate Formation in the Presence of Surfactants. *Processes*, 7(9), [598]. <https://doi.org/10.3390/pr7090598>
- Pandey, J. S., Daas, Y. J., Karcz, A. P., & Solms, N. V. (2020). Enhanced Hydrate-Based Geological CO<sub>2</sub> Capture and Sequestration as a Mitigation Strategy to Address Climate Change. *Energies*, 13(21), <https://doi.org/10.3390/en13215661>



# ACKNOWLEDGEMENTS / THANK YOU / QUESTIONS

For further discussion  
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