ACADEMIC SEMINAR

CO_2 Recovery & Storage by Hydrate Engineering

Hanoi, 05-2024

Outlines

1. Contexts and Objectives
2. CO_2 and Gas Hydrate Backgrounds
3. CO_2 Recovery and Storage by Hydrate Engineering
4. Apparatus-Result-Discussion
5. Conclusions
6. Acknowledgements

1. Contexts and Objectives

- CO_2 emission is a big issue now for greenhouse effect and climate change

- Many methods to be proposed to reduce CO_2 emission by using less CO_2 emission fuel, CO_2 recovery, storage and utilization, etc.

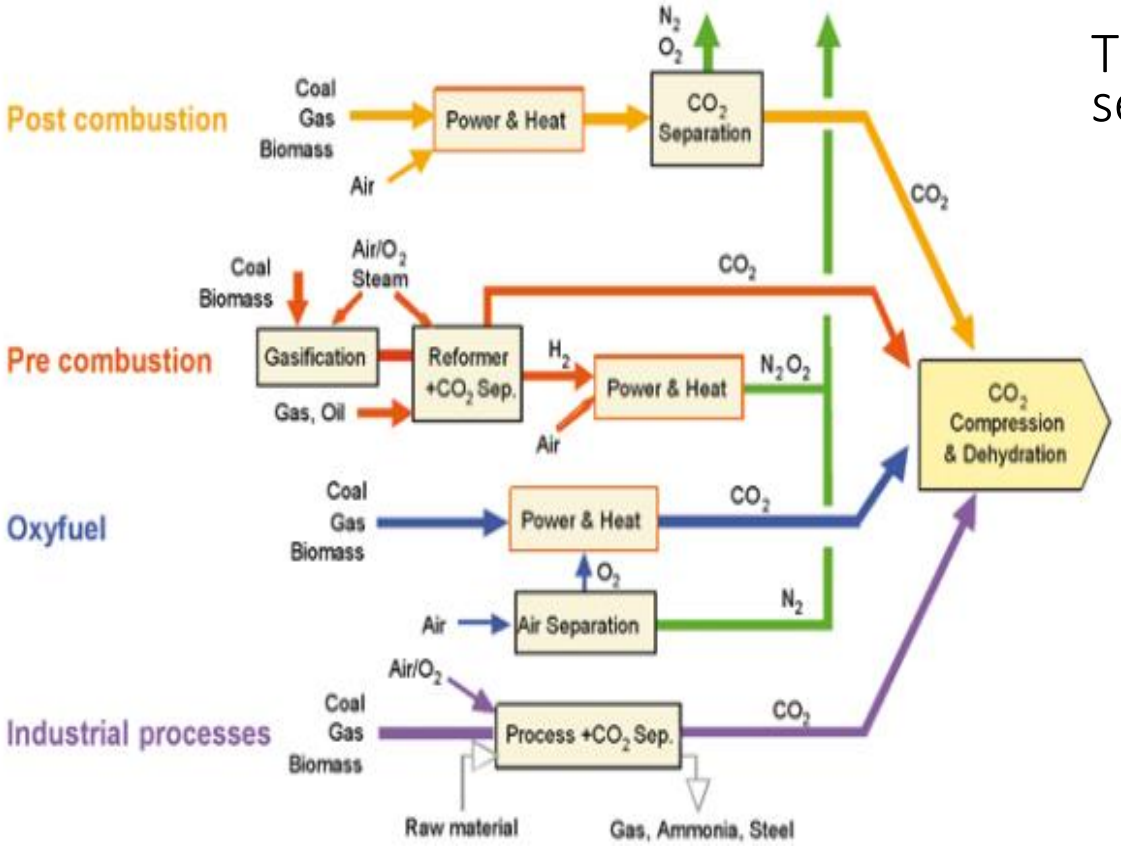
- This work is to report one of the ways to reduce CO_2 emission by CO_2 recovery, storage by hydrate engineering

2. CO_2 and Gas Hydrate Backgrounds

- CO_2 is from natural and man-made sources
- Large amount of CO_2 is emitted in the world and Vietnam today by human that can be managed
- CO_2 may cause the green house effect and climate change

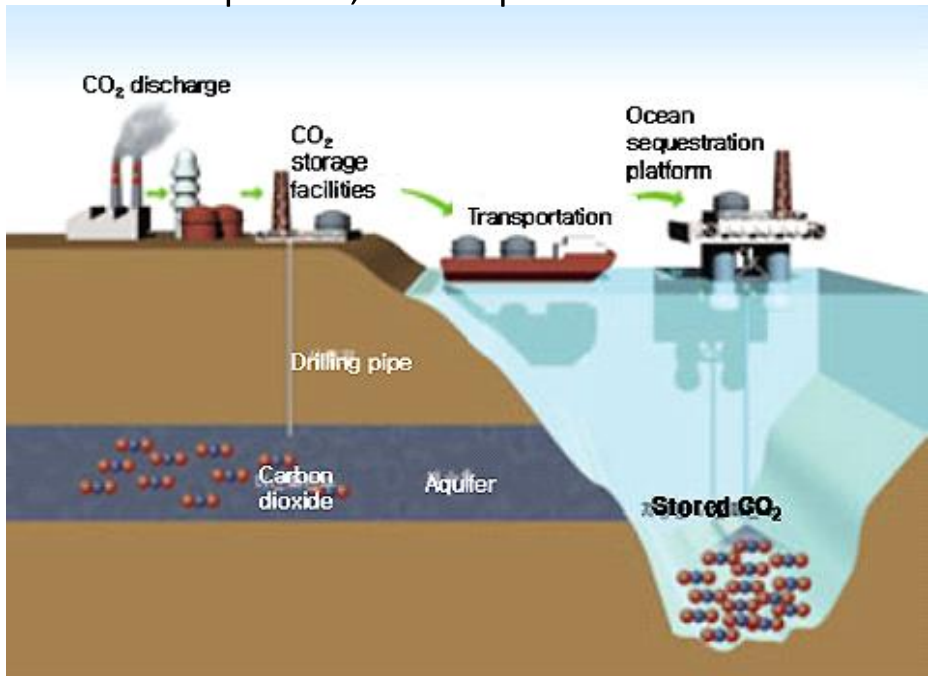
2. CO_2 and Gas Hydrate Backgrounds

Overview of CO_2 capture processes and systems



B. Metz, O. Davidson, H. de Coninck, M. Loos, and L. Meyer, *IPCC Working Group III Special report on carbon dioxide capture and storage*. 2005.

The main steps in carbon dioxide capture and sequestration: capture, transportation and storage

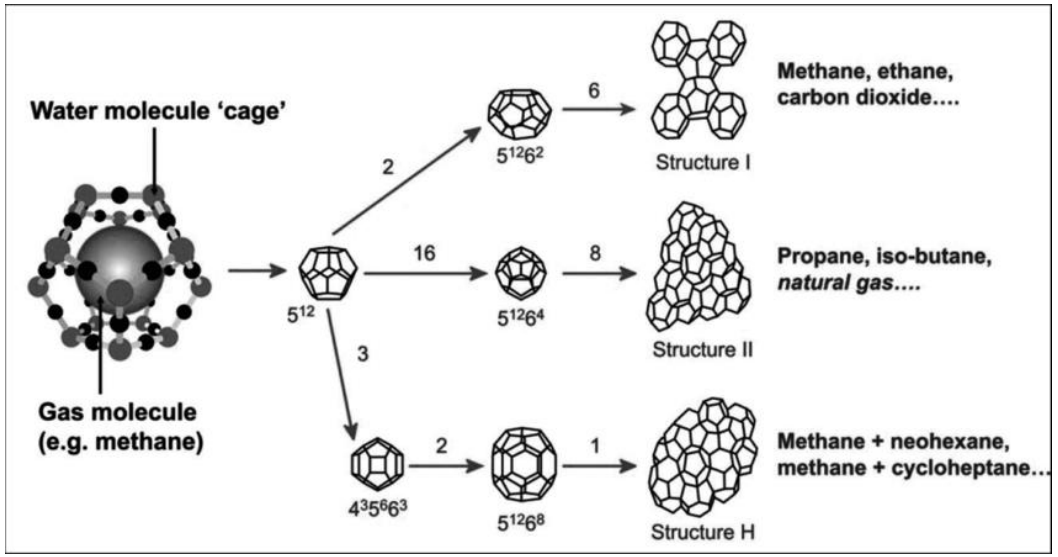


"The future of Carbon Capture and Storage | Energy, Technology, & Policy." [Online]. Available: https://webberenergyblog.wordpress.com/2012/04/06/3272/. [Accessed: 11-Jul-2019].

2. CO_2 and Gas Hydrate Backgrounds

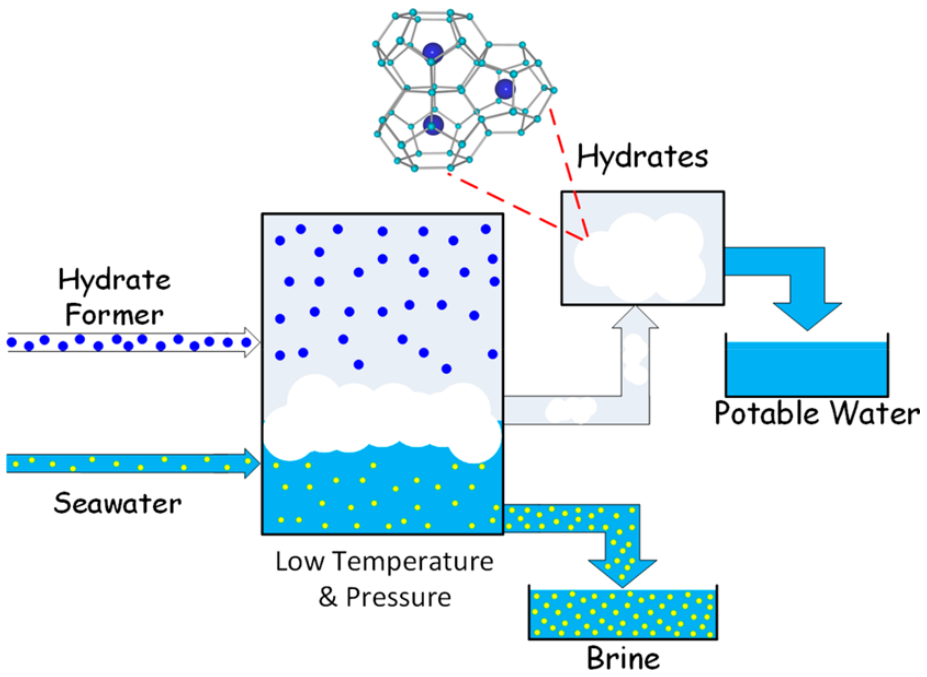
- Hydrate is a solid compound formed by water and guest molecule (hydrocarbons, H_2S, CO_2, H_2, N_2, O_2, etc.) at low temperature and possibly at high pressure.
- Applications of hydrates: methane hydrate resource as a huge future fuel, gas storage and separation, water treatment, flow assurance, etc.

https://www.netl.doe.gov

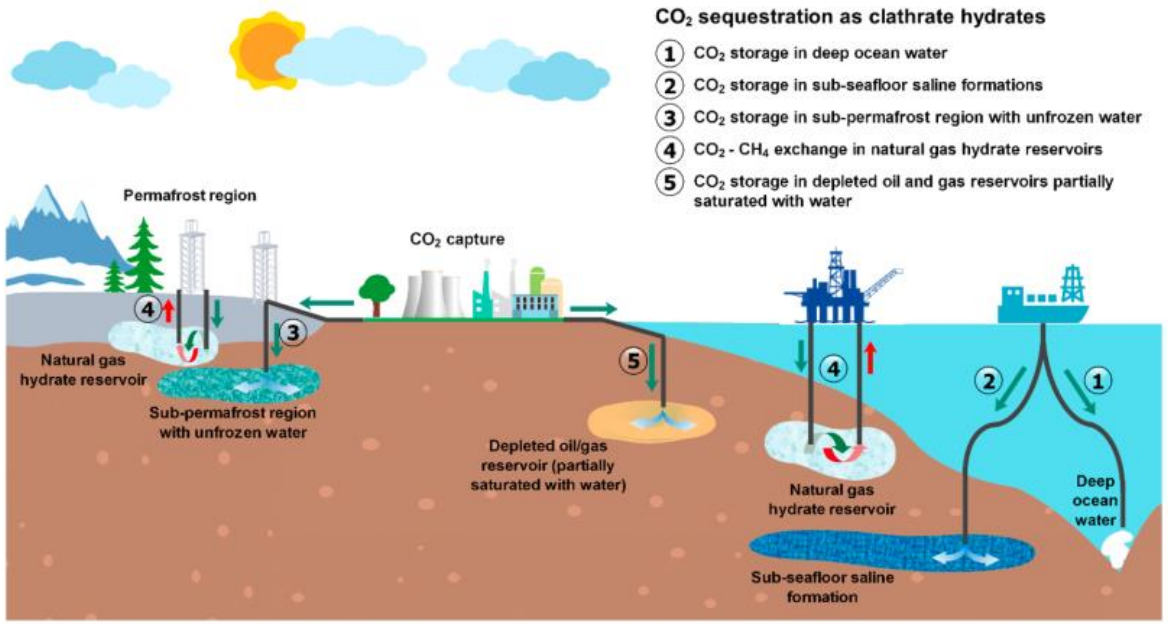


Hydrate structures (from Center for Gas Hydrate Research – Heriot Watt)

2. CO_2 and Gas Hydrate Backgrounds

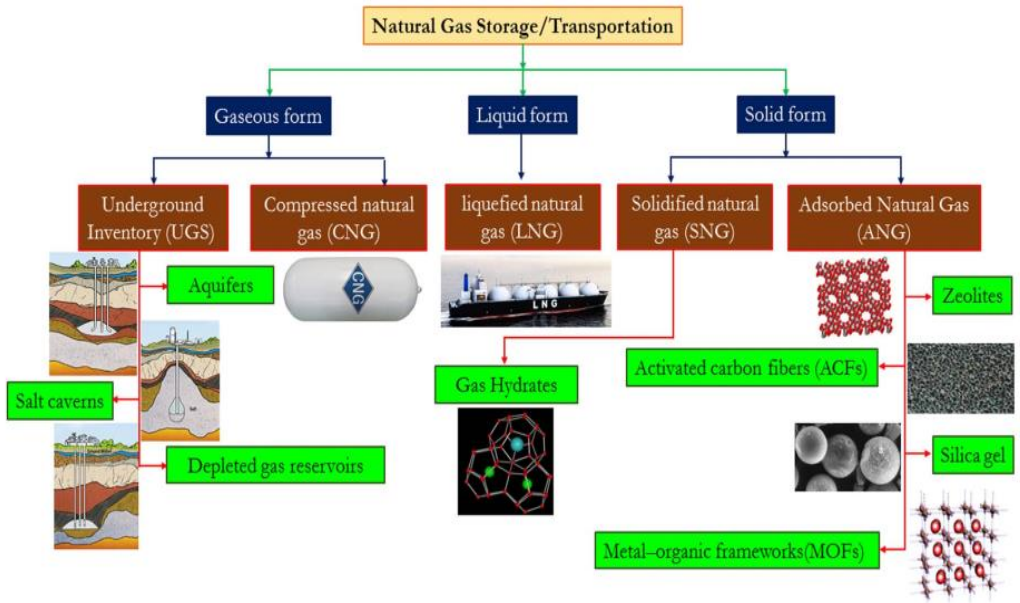


P. Babu, "A review of the hydrate based gas separation (HBGS) process for carbon dioxide pre-combustion capture," *Energy*, 2015

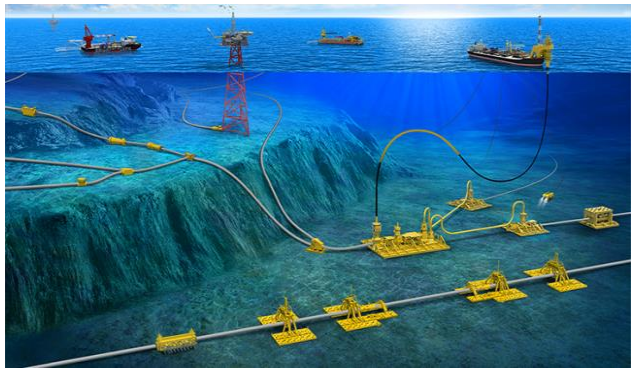


Junjie Zheng, Zheng Rong Chong, M. Fahed Qureshi, and Praveen Linga*. **Carbon Dioxide Sequestration via Gas Hydrates: A Potential Pathway toward Decarbonization**, *Energy Fuels* 2020

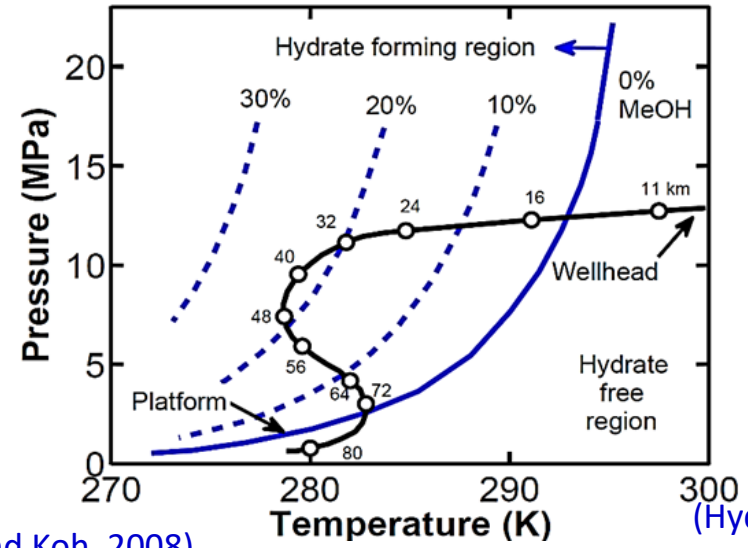
2. CO_2 and Gas Hydrate Backgrounds



Pathways for natural gas storage and transportation (Images on UGS obtained from http://www.energyinfrastructure.org/energy-101/natural-gas-storage).



(Subsea pipelines - Oilstates, 2017)



(Sloan and Koh, 2008)

(Hydrate recovered at slug catcher-Petrobras)

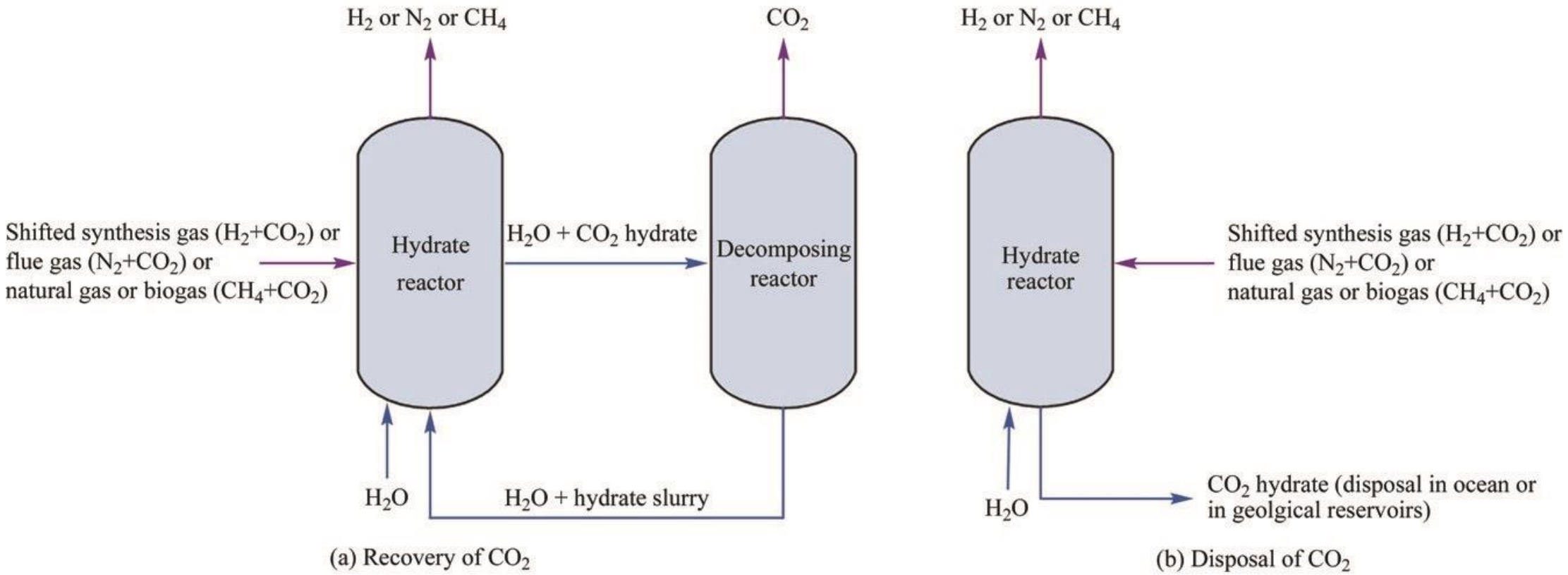
3. CO_2 Recovery and Storage by Gas Hydrate Engineering

- There are many ways to recover and store CO_2 in the industry (using absorbed solvents to capture CO_2 in the exhausted gases; store CO_2 in the ocean and/or underground geological, mineral carbonation).

- This work will show the updated **CO_2 Recovery and Storage by Gas Hydrate Engineering.**

3. CO_2 Recovery and Storage by Gas Hydrate Engineering

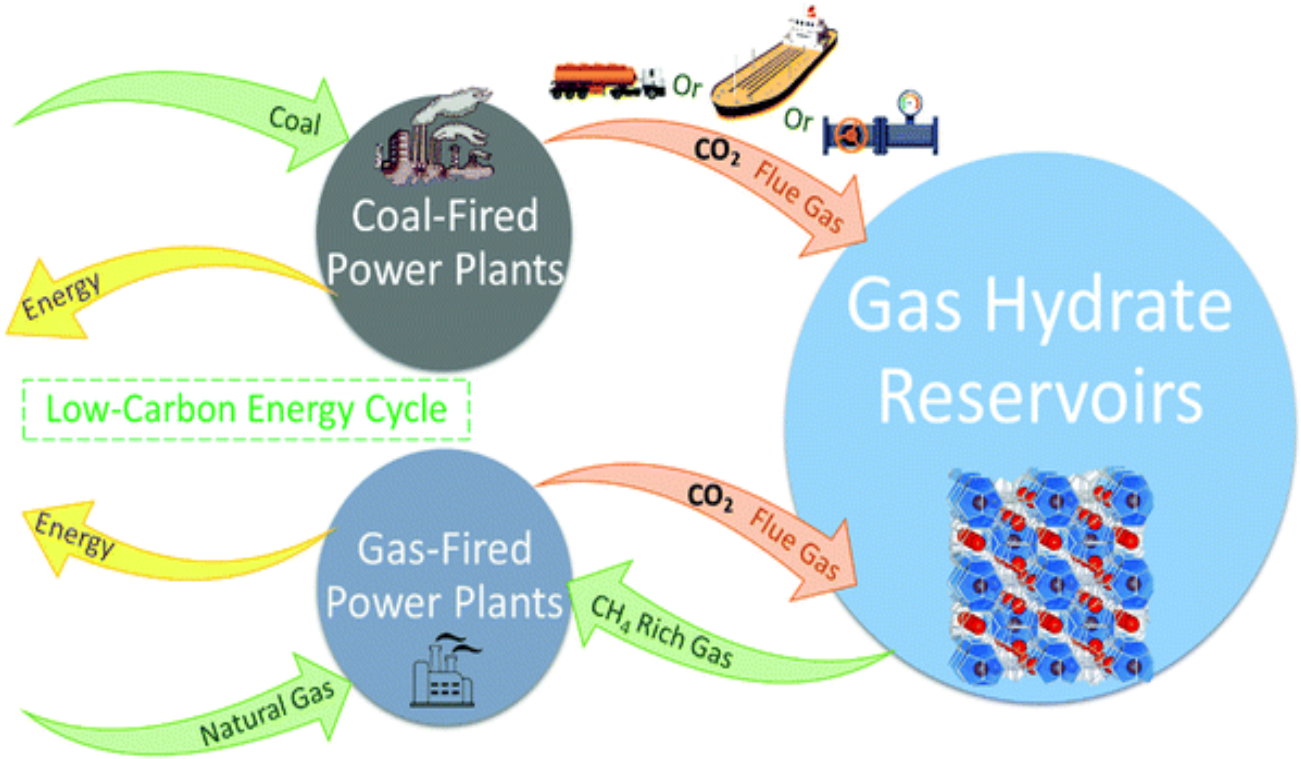
Process of CO_2 capture from shifted synthesis gas, flue gas, sour natural gas or biogas



Yanhong Wang, Xuemei Lang, Shuanshi Fan (2013), Hydrate capture CO_2 from shifted synthesis gas, flue gas and sour natural gas or biogas, China

3. CO_2 Recovery and Storage by Gas Hydrate Engineering

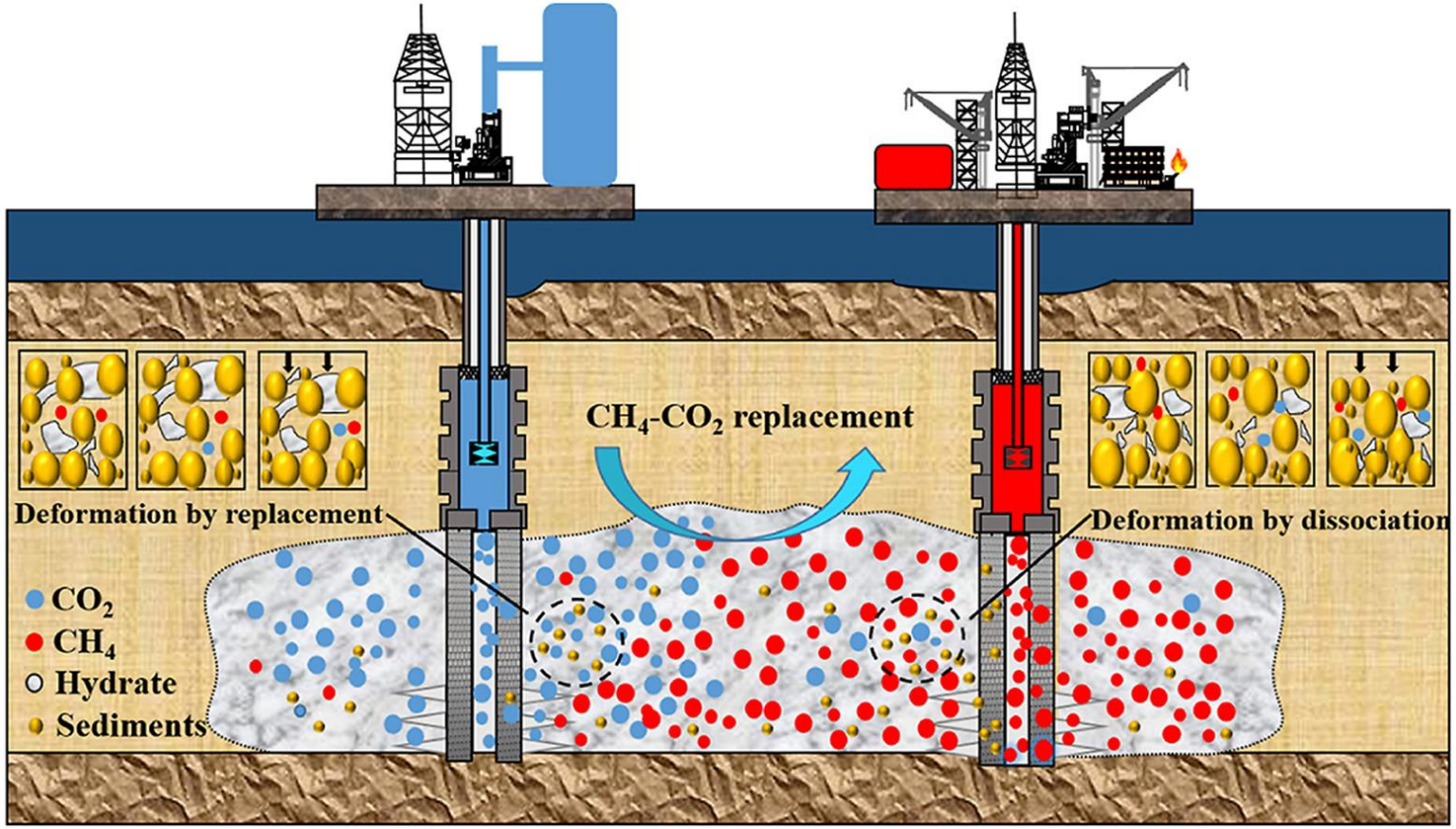
Illustration of the principal mechanism of the direct injection of flue gas for methane recovery from gas hydrate reservoirs and CO_2 capture and storage simultaneously



Aliakbar Hassanpouryouzband , Edris Joonaki, Mehrdad VasheGHsani Farahani, Satoshi Takeya , Carolyn Ruppel , Jinhai Yang , Niall J. English , Judith M. Schicks , Katriona Edlmann , Hadi Mehrabian , Zachary M. Aman and Bahman Tohidi (2020), *Gas hydrates in sustainable chemistry*

3. CO_2 Recovery and Storage by Gas Hydrate Engineering

Storage CO_2 in natural gas hydrate reservoirs and recovery CH_4



Tingting Luo et al., Deformation behaviors of hydrate-bearing silty sediments during CH_4–CO_2 replacement, Journal of Petroleum Science and Engineering, 2022

3. CO_2 Recovery and Storage by Gas Hydrate Engineering

* Future work for CO_2 Recovery and Storage by Gas Hydrate Engineering:

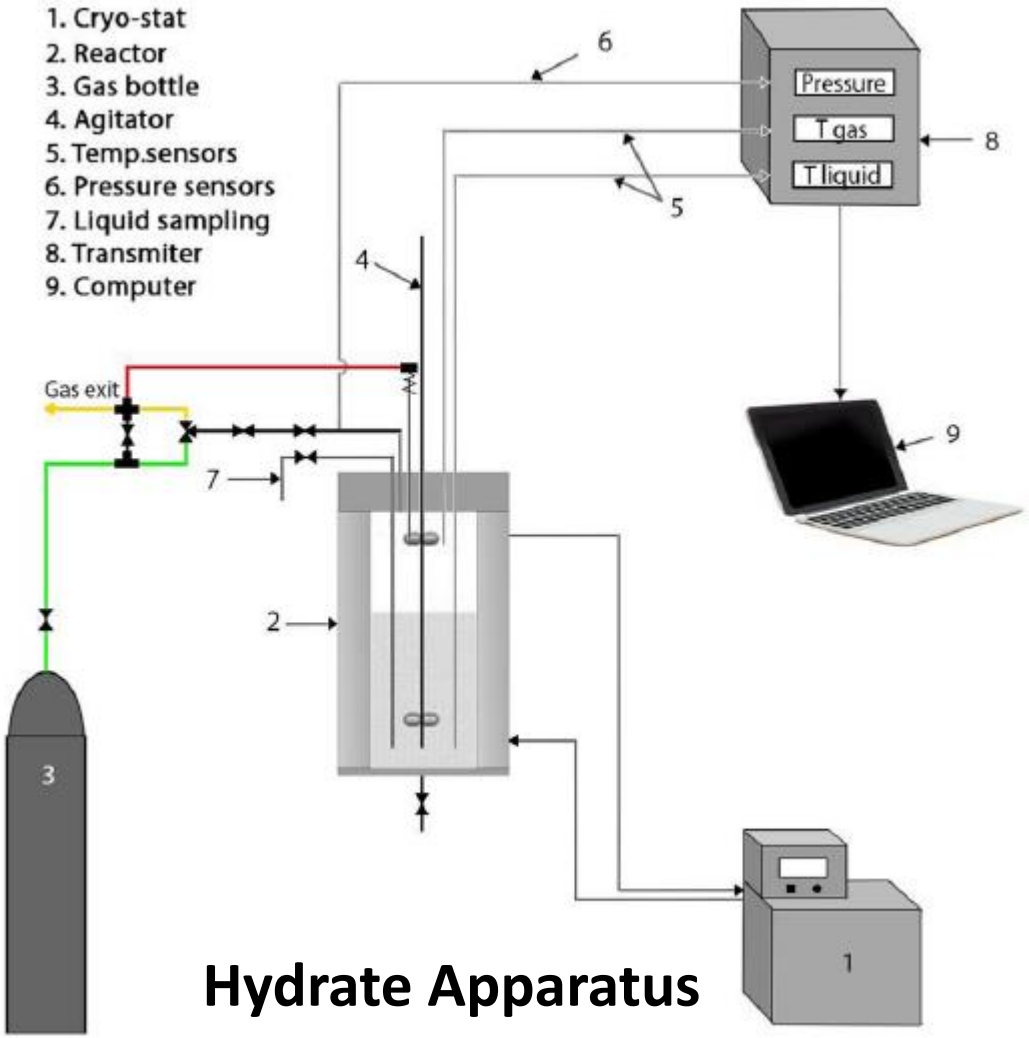
- Develop (Enhance) Hydrate-based gas (CO_2) separation technology (good hydrate formation promoter, improve kinetics by mechanical methods and additives)
- Natural gas hydrate recovery by CH_4-CO_2 exchange
- Conditions and techniques to store CO_2 under the seafloor by hydrate engineering

4. Apparatus-Result-Discussion

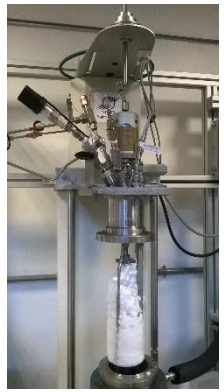
- Cyclopentane (CP) is used as hydrate former due to:
  - (1) high efficiency for CO_2 hydrate formation
  - (2) low energy cost
  - (3) readily available process materials
- In this research, CP-CO_2 hydrates are investigated for CO_2 recovery and storage with thermodynamics and kinetics.

4. Apparatus-Result-Discussion

Hydrate Thermodynamics & Kinetics

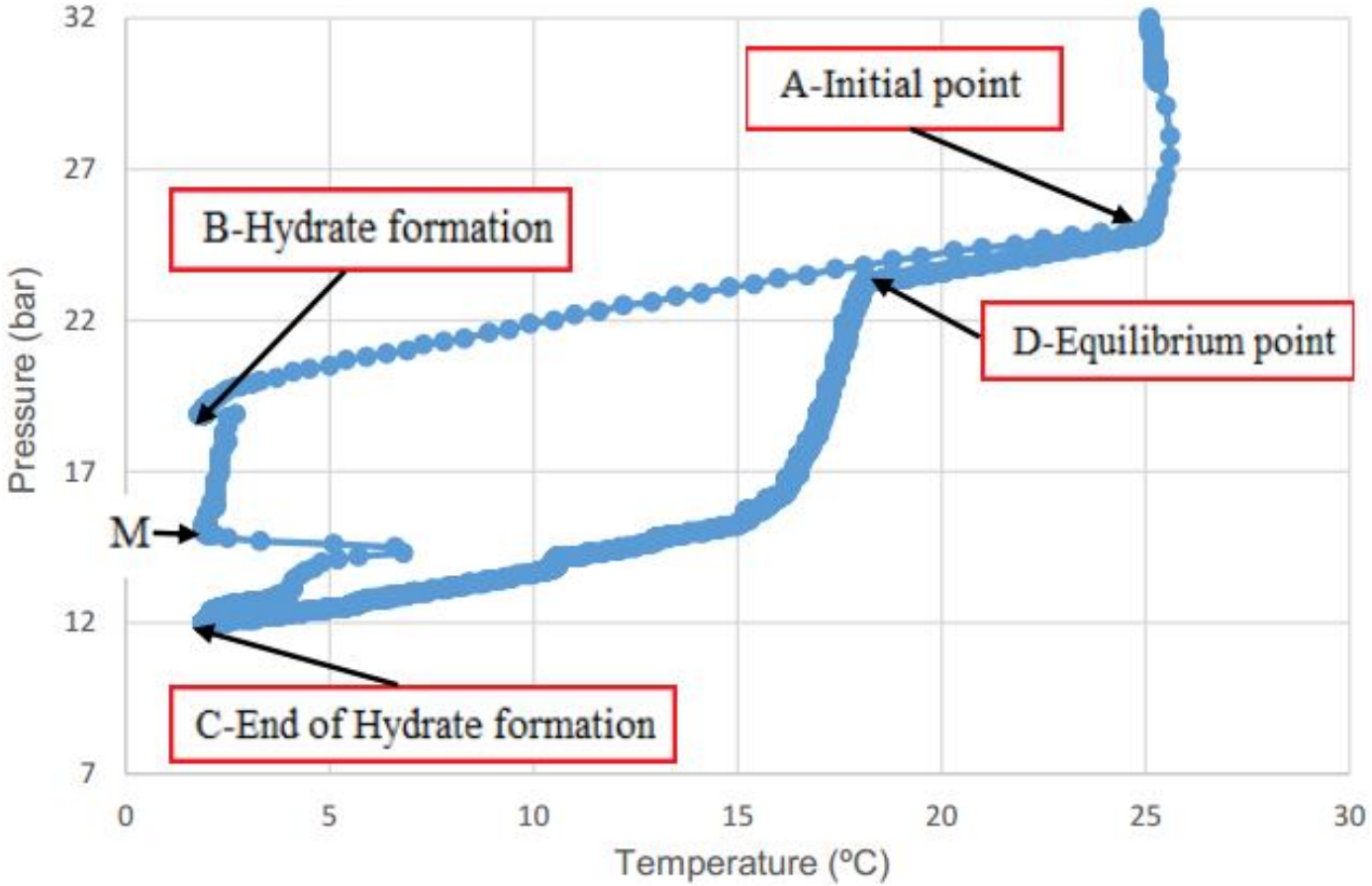


Hydrate Apparatus



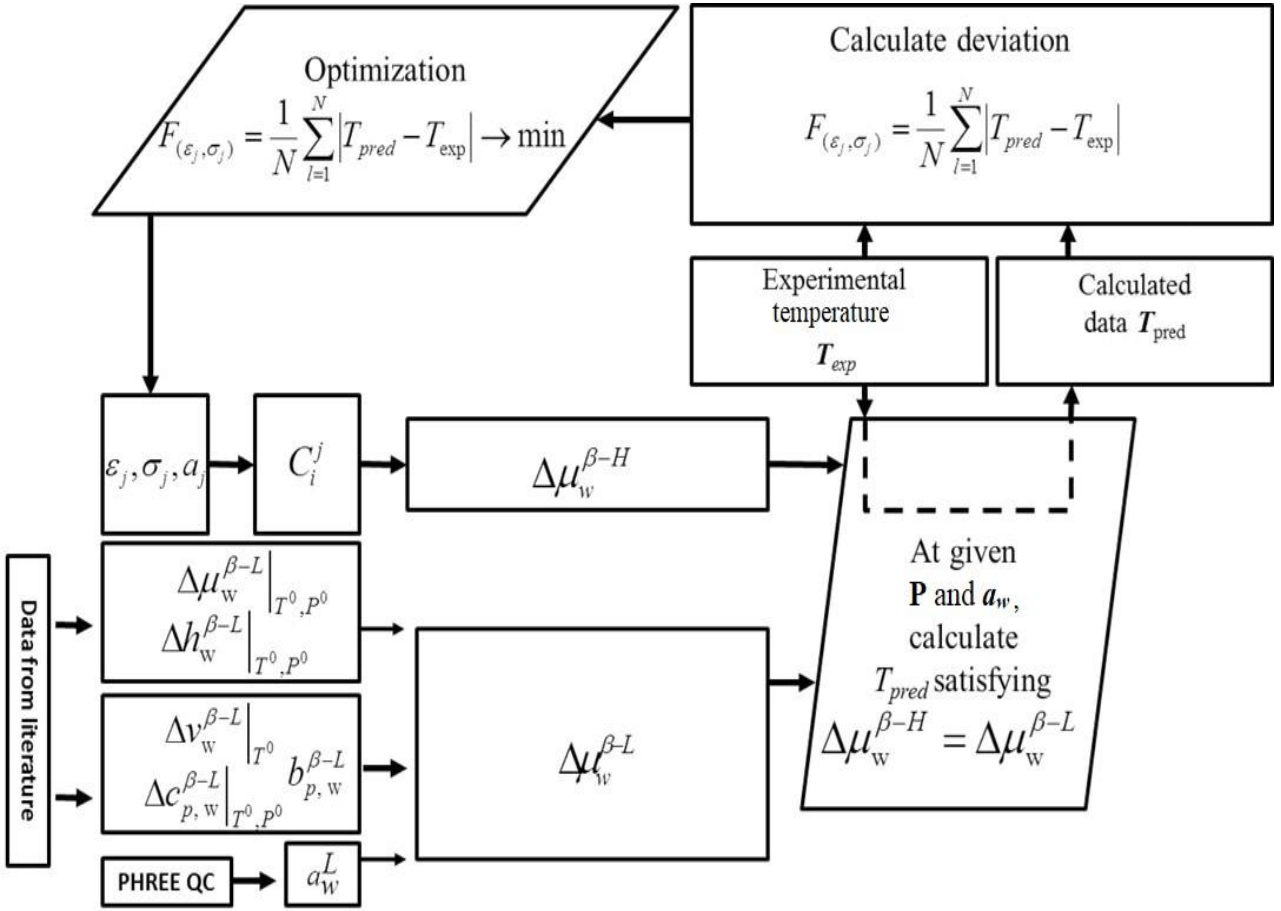
4. Apparatus-Result-Discussion

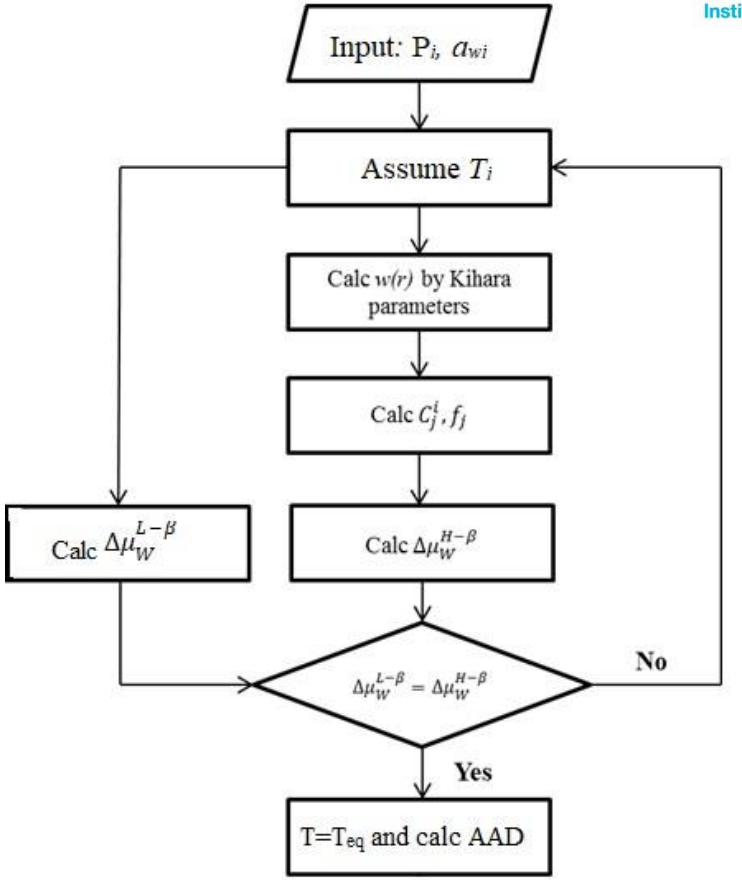
CP-CO_2-Hydrate Thermodynamics (Equilibrium & Modelling)



4. Apparatus-Result-Discussion

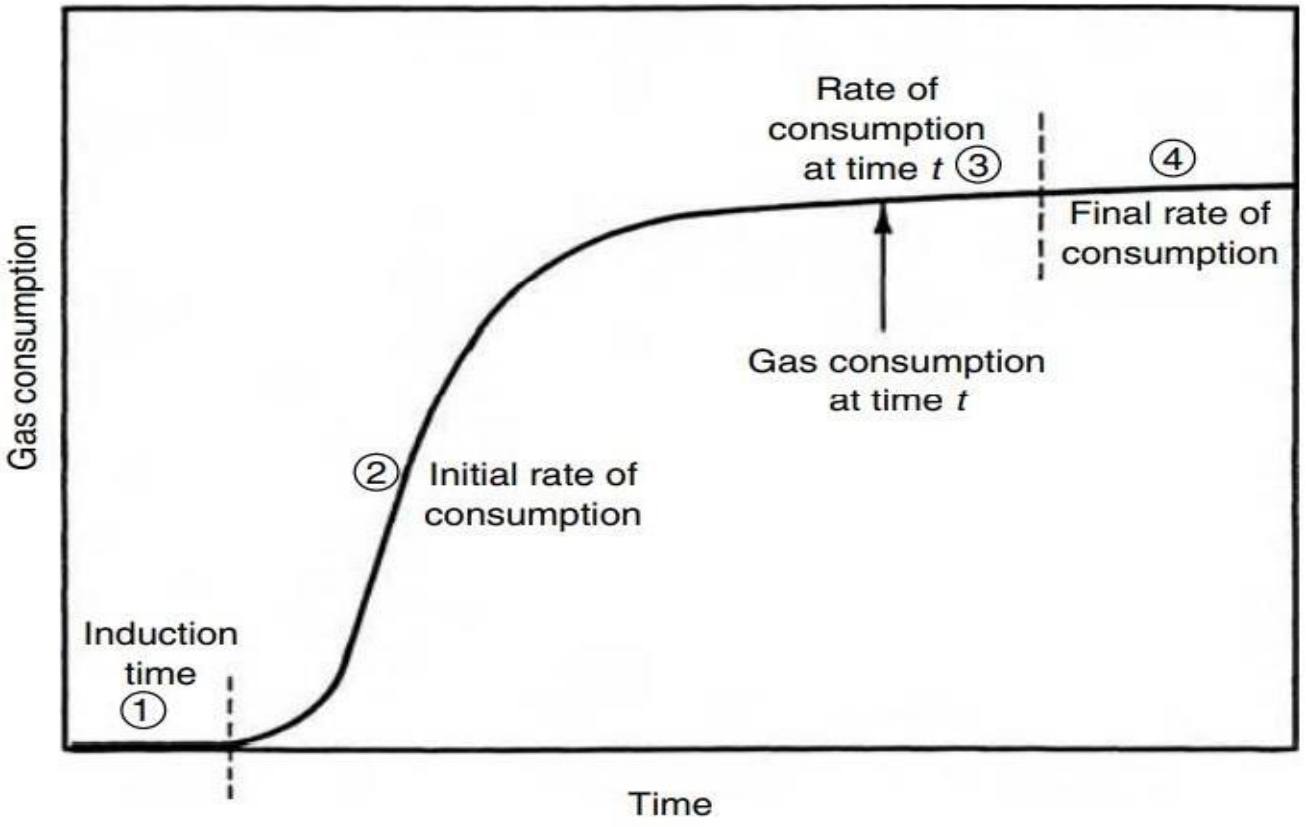
CP-CO_2-Hydrate Thermodynamics (Equilibrium & Modelling)





4. Apparatus-Result-Discussion

CP-CO_2-Hydrate Kinetics



Sloan, E.; Koh, C.A. *Clathrate Hydrates of Natural Gases*, 3rd ed.; Taylor and Francis Group: Abingdon, UK, 2008

4. Apparatus-Result-Discussion

CP-CO_2 hydrates (Thermodynamics & Kinetics) - Experimental Results

1. Finish experiments with Thermodynamics & Kinetics of CP-CO_2 hydrate without/with NaBr (P=27; 32; 37 bar)
2. Finish experiments with Thermodynamics & Kinetics of CP-CO_2 hydrate without/with KBr (P=27; 32; 37 bar)
3. Finish experiments with Thermodynamics & Kinetics of CP-CO_2 hydrate without/with Na_2SO_4 (P=27; 32; 37 bar)
4. Finish experiments with Thermodynamics & Kinetics of CP-CO_2 hydrate without/with K_2SO_4 (P=27; 32; 37 bar)
5. Finish experiments with Kinetics of CP-CO_2 hydrates with 3.5-7%wt NaCl (effects of temperature, pressure, agitation speed, CP amount)

4. Apparatus-Result-Discussion

Future work

1. Doing experiments of CO_2 hydrate in the presence of additives (CP, SDS, etc.)
2. Doing experiments of CO_2 hydrate in the presence of salts
3. Doing experiments of CO_2 hydrate in the presence of solids (sediments)
4. Stability of CO_2 hydrate in the presence of additives, salts, solids (sediments)

5. Conclusions

1. These days, CO_2 Recovery and Storage are becoming more importantly
2. CO_2 Recovery and Storage can be done by many ways and by Gas Hydrate Engineering
3. Cyclopentane (CP) can be used as hydrate former
4. **In this research, CP-CO_2 hydrates are investigated for** CO_2 Recovery and Storage **with thermodynamics and kinetics**
5. **Future work can be CO_2 hydrate in the presence of** additives, salts, solids (sediments) and its stability in these conditions

6. Acknowledgements

1. SPIN Centre, Saint-Etienne School of Mines (EMSE)
2. Petroleum and Energy Faculty, Hanoi University of Mining and Geology (HUMG)
3. International Co-operation Office (EMSE and HUMG)
4. Oil Refining and Petrochemicals Department (HUMG)
5. Advanced Program in Chemical Engineering (HUMG)