Status of UREP Research Tasks

PHASE BEHAVIOR IN NANOPOROUS MEDIA

Xiaolong Yin, Petroleum Engineering, Colorado School of Mines

UREP research tasks on phase behavior

PROJECT 1 Flow and Transport of Hydrocarbon Fluids in Nano-Porous Reservoirs	Phase 3 Tasks
	1. Understand trends in field data 2. Dew-point measurements in nanofluidic chips and comparison with models 3. Effect of temperature on experiments 4. Core measurements 5. Upscaling experimental results 6. Molecular simulations

Tucge Calisgan (PhD)
PVT study of field data

Kaia Corp.
Non-intrusive optical measurement of pressure

Asm Kamrruzaman (PhD)
Modeling phase behavior with capillary pressure

Keerthana Krishnan (MS)
Capillary condensation in nanosililca

Research tasks on phase behavior (T2 & T3)

T2 – Sponsored by DOE STTR – Kaia Corp.

- Phase behavior of C_3 in nanofluidics
- Comparison with Kelvin equation (had difficulties in matching)
- Measure pressure change in the vicinity of phase change

T3 – Asm Kamrruzaman

- Repeat previous C_3 experiments
- Design pressure / temperature enclosures
- Conduct nanofluidic experiments at different temperatures
- Experiments with mixtures and compare with model

Green = Completed; Yellow = Current; White = Planned

Research tasks on phase behavior (T4)

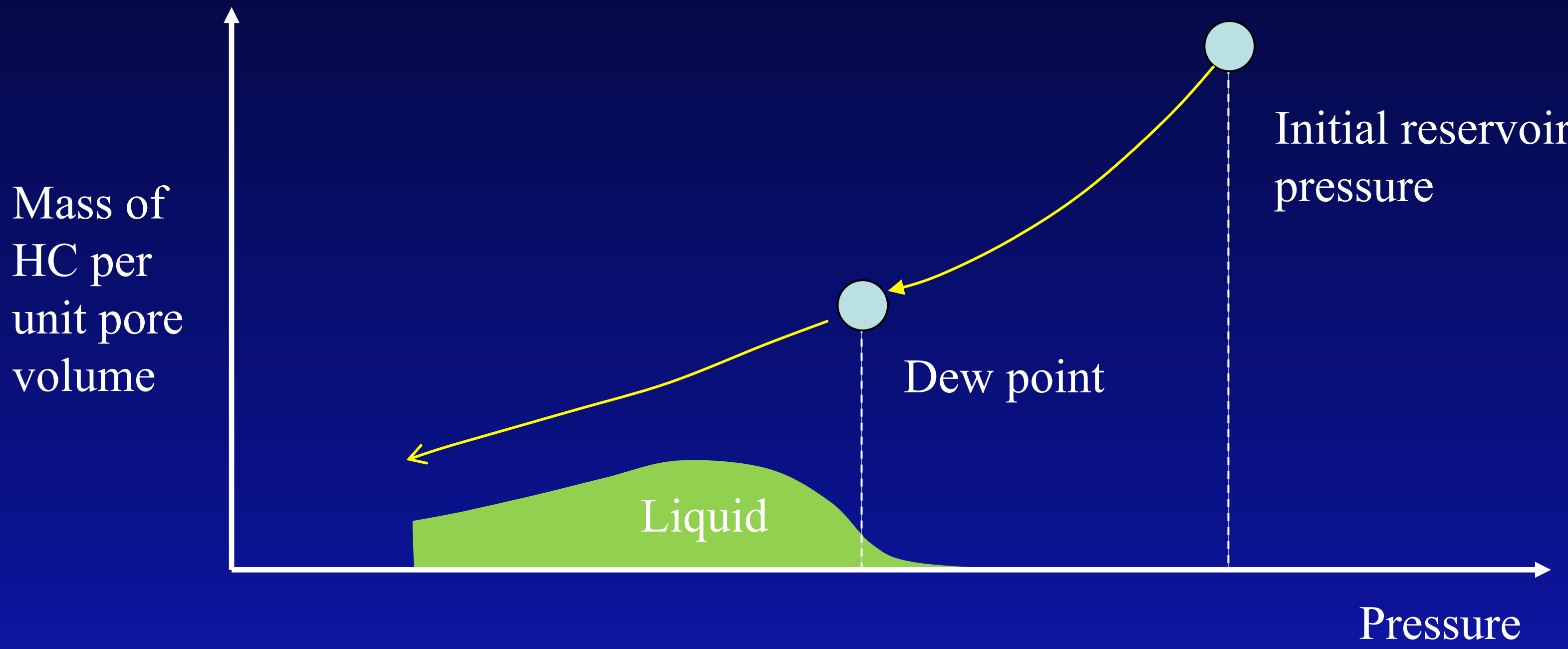
T4 – Keerthana Krishnan

- Capillary condensation of C_3 in Niobrara
- Capillary condensation of C_3 in synthetic nanopores
- Other rocks
- Other gas or gas mixtures
- Effect of water
- Effect of crushing
- Compare with upscaled models (T5 – core level)

Research tasks on phase behavior (T4)

Plan for T4

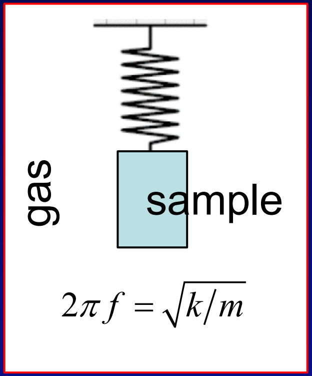
Experimentation and model for HC in place that accounts for the effect of capillary condensation for condensate reservoirs



Research tasks on phase behavior (T4)

Main progress for T4

Original design in Larson et al. (2017) and Cho et al. (2017)

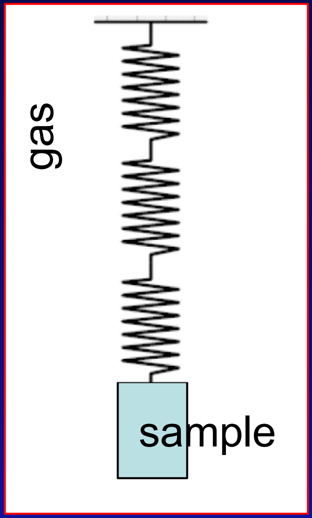


P/T cell
Single spring
60-100 g
0.1 g sensitivity

However it is difficult to get 60 g of nanosilica materials

Options

- ~~Using a flexible beam~~
- Using multiple springs



P/T cell
Multiple springs
6-100 g
Sensitivity TBD

Starting from summer we will conduct experiments on nanosilica materials

Research tasks on phase behavior (T5)

T5

Vapor-liquid phase behavior in a <u>single pore</u>

Vapor-liquid phase behavior in <u>multiple pores</u> (pore size distribution)

General multi-phase (≥ 3) equilibrium

- Model constructed and validated using data from literature
- CO_2-oil-water and C_2-oil-water phase behavior measured
- Writing papers …

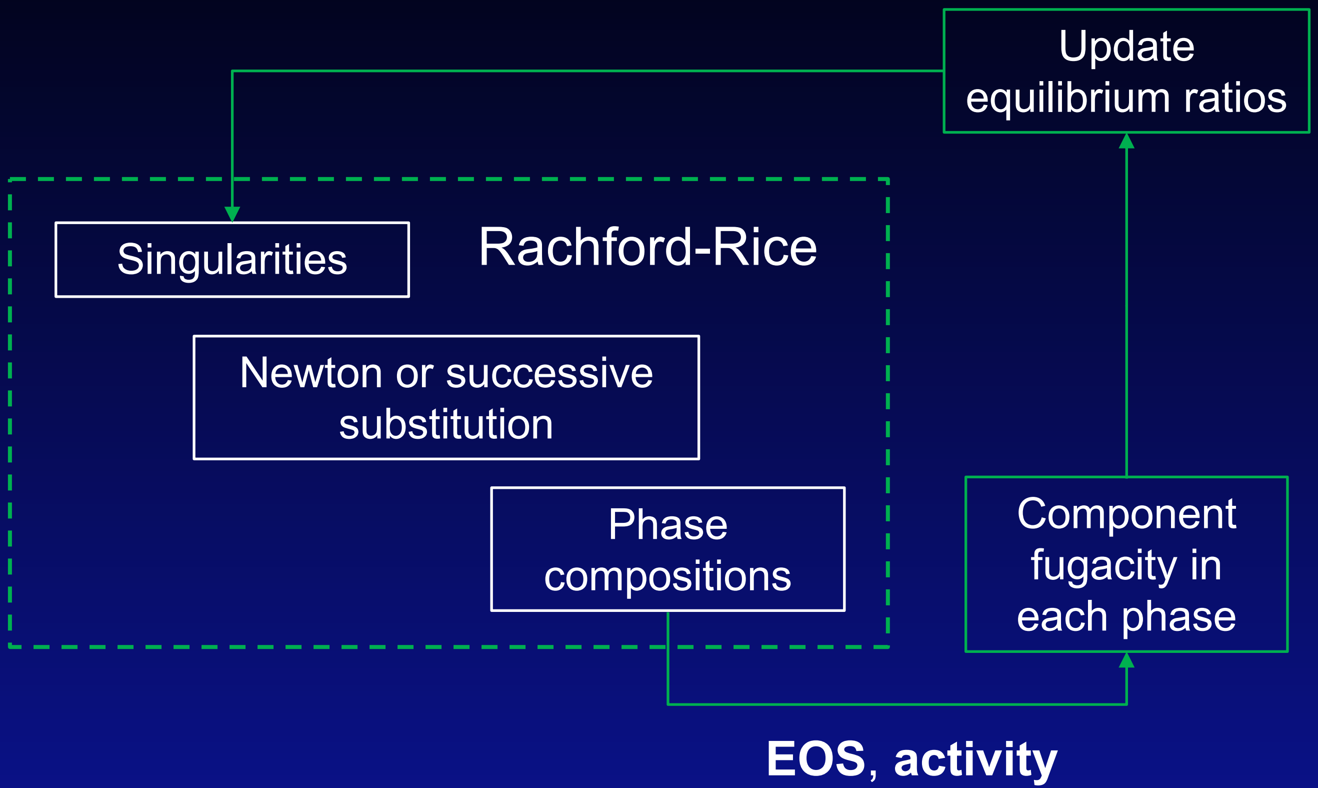
Vapor-liquid-adsorption phase behavior

Upscale to the <u>*core*</u> level, considering equilibrium among pores of different sizes but no variation in pressure and temperature

Coz-Sim

Upscale to the <u>*reservoir*</u> level, considering pressure variations due to flow, and explain and predict field data (T1)

Flow chart of 3-phase calculations



Work completed

- EOS and activity models have been implemented
- Gas-oil phase behavior with water can now be done

(Example) result of 3-phase calculations

Component	Composition (%)
C_1	30
nC_5	15
nC_{10}	25
CO_2	10
H_2S	10
H_2O	10

- Peng-Robinson EOS for oil and gas phases
- Henry's law for aqueous phase
- Results are in good agreement with Li and Nghiem (1986)

	This study			Li and Nghiem (1986)			Two-phase	
	x^l %	x^g %	x^w %	x^l %	x^g %	x^w %	x^l %	x^g %
C_1	22.868	65.174	0.001	22.884	65.220	0.001	23.286	66.365
nC_5	21.676	4.936	0	20.216	4.603	0	20.585	4.687
nC_{10}	35.919	0.663	0	35.889	0.662	0	35.959	0.664
CO_2	9.145	16.873	0.020	9.148	16.879	0.021	9.239	17.047
H_2S	10.906	11.220	0.141	10.906	11.219	0.141	10.929	11.243
H_2O	0.958	1.416	99.773	0.958	1.417	99.839	/	/
	$\tilde{n}^l$	$\tilde{n}^g$	$\tilde{n}^w$	$\tilde{n}^l$	$\tilde{n}^g$	$\tilde{n}^w$	$\tilde{n}^l$	$\tilde{n}^g$
	69.20	21.75	9.05	69.26	21.70	9.04	77.45	22.55

Research tasks on phase behavior (T6 & T1)

T6 – progressing

Characterize bulk phase behavior of a pure substance

Characterize confined phase behavior of a pure substance

Characterize confined phase behavior of mixtures

Compare with model (T5 - pore) and experiments (T2 and T3)

T1

Field data acquired and being analyzed

Use Coz-Sim to simulate field cases and compare (T5 – reservoir)

Green = Completed; Yellow = Current; White = Planned

Phase behavior in nanopores – integration

- Molecular simulations

  Molecular scale
  T6 Inter-molecular interactions

- Fluid property models

  Density correlations
  Phase transitions
  T5 Equilibrium across many pores

- Reservoir engineering tools

  Reserve estimation
  Understand decline
  Reservoir simulation T1

- Nanofluidic experiments

  Pore scale
  Direct observations T2, T3

- Core experiments

  Verification of predictions

  T4