
Contribution ID: **521**    Type: **Oral Presentation**

# Pore-scale Ostwald ripening of residually trapped CO2 in the presence of oil and water at immiscible and near-miscible conditions

*Monday, 22 May 2023 17:45 (15 minutes)*

Subsurface CO2 storage is a means to limit emissions to the atmosphere and global warming. Residual trapping, which occurs when brine invades the pore space occupied by the migrating CO2 plume and creates disconnected CO2 ganglia, is one of the mechanisms by which significant amounts of CO2 can be stored safely in the subsurface [1]. Experiments on rock samples show that larger amounts of CO2 can be residually trapped in the presence of both oil and water [2], suggesting depleted hydrocarbon reservoirs are suitable sites for CO2 storage. However, reservoir conditions and fluid compositions vary widely, leading to different three-phase displacement mechanisms and residual trapping from miscible to immiscible conditions. Further, mass transfer between phases may change the amount of residually trapped CO2 over time.

A residually trapped gas-bubble distribution will undergo mass exchanges through Ostwald ripening. It is a process that leads to mass transfer from bubbles having a higher chemical potential to bubbles with a lower chemical potential. Our previous study on three-phase ripening [3] has highlighted that the ripening of gas bubbles in the presence of oil and water can lead to different residual gas volumes in the two liquids and different order of bubble loss during evolution. In this work, we will analyse the impact of partial gas miscibility on ripening evolution.

This study uses a chemical-potential difference and level-set based methodology [3-5] that calculates mass transfer between bubbles through diffusion paths in oil and water and across oil/water interfaces. We use the Peng-Robinson equation of state to calculate gas bubble fugacity at reservoir conditions. We perform simulations on different idealised 2D homogeneous and heterogeneous porous media. In the 2D heterogeneous medium, we simulate oil-water-gas-water invasion cycles to generate residual phase volumes. We also use 3D pore-space images of a water-wet sandstone to simulate Ostwald ripening in near-miscible conditions on residual three-phase fluid configurations with isolated oil and gas ganglia obtained after a water-alternate-gas invasion cycle. We quantified the evolution of pressure, volume, surface area, and the number of residual bubbles, for different initial fluid distributions and saturations.

Our results show that the gas-liquid interfacial tensions, gas-liquid contact angles, and oil-water capillary pressures determine the residual gas bubble sizes in each liquid phase. Specifically, we find that the equilibrium volume of bubbles in the oil phase, as well as the range of bubble volumes in oil and water, are smaller for near-miscible conditions than for immiscible conditions. This decrease is due to larger gas-liquid contact angles in the near-miscible case creating smaller gas bubble pressure differences and less mass transfer (and lower mass transfer rate) even though the ratio of gas-water to gas-oil interfacial tensions increases with partial miscibility. During fluid redistribution, we also identify cases where the bubble coarsening leads to capillary instabilities and three-phase double displacements (e.g., oil displaces a gas bubble that displaces water), which can lead to lower residual gas trapping.

## Participation

In-Person

## References

[1] Krevor, S., Blunt, M.J., Benson, S.M., Pentland, C.H., Reynolds, C., Al-Menhali, A., & Niu, B. (2015) Capillary trapping for geologic carbon dioxide storage –from pore scale physics to field scale implications, International Journal of Greenhouse Gas Control, 40, 221-237. DOI: https://doi.org/10.1016/j.ijggc.2015.04.006
[2] Alhosani, A., Bijeljic, B., and Blunt, M. J. (2021). Pore-scale imaging and analysis of wettability order, trapping and displacement in three-phase flow in porous media with various wettabilities, Transport in Porous Media, 140, 59-84. DOI: https://doi.org/10.1007/s11242-021-01595-1
[3] Singh, D., Friis, H.A., Jettestuen, E., & Helland, J.O. (2022). A pore-scale level-set approach to Ostwald ripening of gas bubbles in porous media in the presence of residual oil and water, Interpore 2022
[4] Jettestuen, E., Friis, H.A., & Helland, J.O. (2021). A locally conservative multiphase level set method for capillary-controlled displacements in porous media. J. Comput. Phys., 428, 109965. DOI: https://doi.org/10.1016/j.jcp.2020.109965
[5] Singh, D., Friis, H.A., Jettestuen, E., & Helland, J.O. (2022). A level set approach to Ostwald ripening of trapped gas bubbles in porous media. Transport in Porous media, 145, 441-474. DOI: https://doi.org/10.1007/s11242-022-01859-4

## MDPI Energies Student Poster Award

No, do not submit my presenation for the student posters award.

## Country

Norway

## Acceptance of the Terms & Conditions

Click here to agree

## Energy Transition Focused Abstracts

This abstract is related to Energy Transition

**Primary authors:** Mr SINGH, Deepak (University of Stavanger); Dr FRIIS, Helmer Andrè (University of Stavanger); Dr JETTESTUEN, Espen (NORCE Norwegian Research Centre); Dr HELLAND, Johan Olav (NORCE Norwegian Research Centre)

**Presenter:** Dr HELLAND, Johan Olav (NORCE Norwegian Research Centre)

**Session Classification:** MS09

**Track Classification:** (MS09) Pore-scale modelling