Effect of the mass transfer on the monitoring of a salt cavern storage

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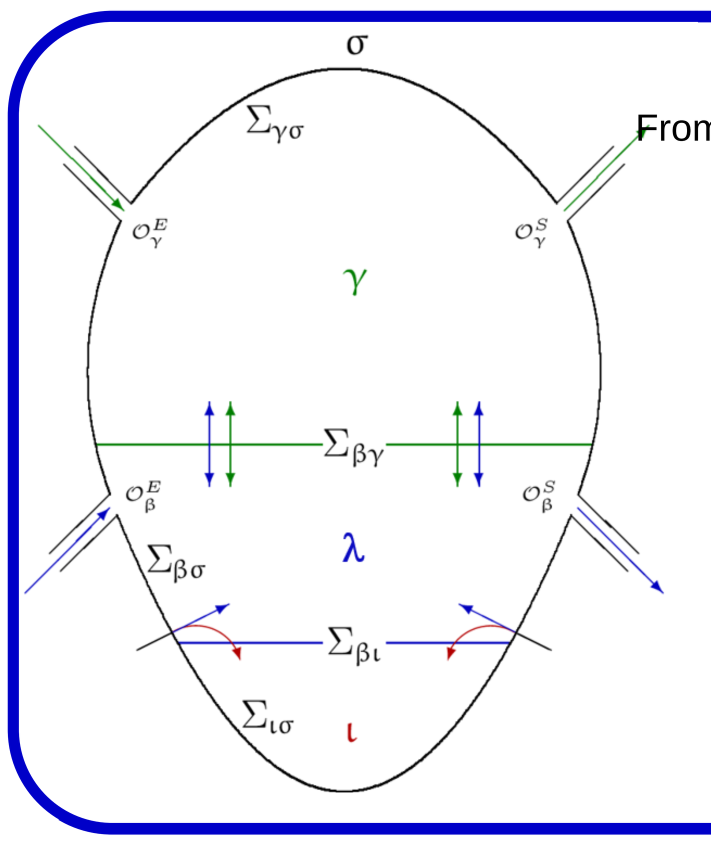
Salt cavern modelisation

From Rouabhi and al. (A multiphase multicomponent modeling approach of underground salt cavern storage, Geomechanics for Energy and the Environment, 2017)



- γ stored fluid phase
- λ brine phase
- ι insoluble materials
- σ rock salt surroundings
- Σ phase interface
- $\mathcal{O}$ surface for in- and outcoming fluid mass (superscripts E and S resp.)

Global equation

$$\begin{pmatrix} \sum_\alpha \mathcal{M}_\alpha \nu_\alpha A_{p\alpha} & -\sum_\alpha \mathcal{M}_\alpha \nu_\alpha B_{T\alpha} \\ \sum_\alpha \mathcal{M}_\alpha c_{p\alpha} & -\sum_\alpha \mathcal{M}_\alpha \nu_\alpha A_{p\alpha} T \end{pmatrix} \begin{pmatrix} \mathrm{d}T/\mathrm{d}t \\ \mathrm{d}p/\mathrm{d}t \end{pmatrix} = \begin{pmatrix} \mathrm{d}\mathcal{V}/\mathrm{d}t - \sum_\alpha \sum_k \mathcal{M}_{k\alpha} \overline{\nu}_{k\alpha} \\ \Psi^\sigma + \Psi^E + \hat{\Psi} \end{pmatrix}$$

Condition on concentrations (considering the mass transfer between the both fluid phases)

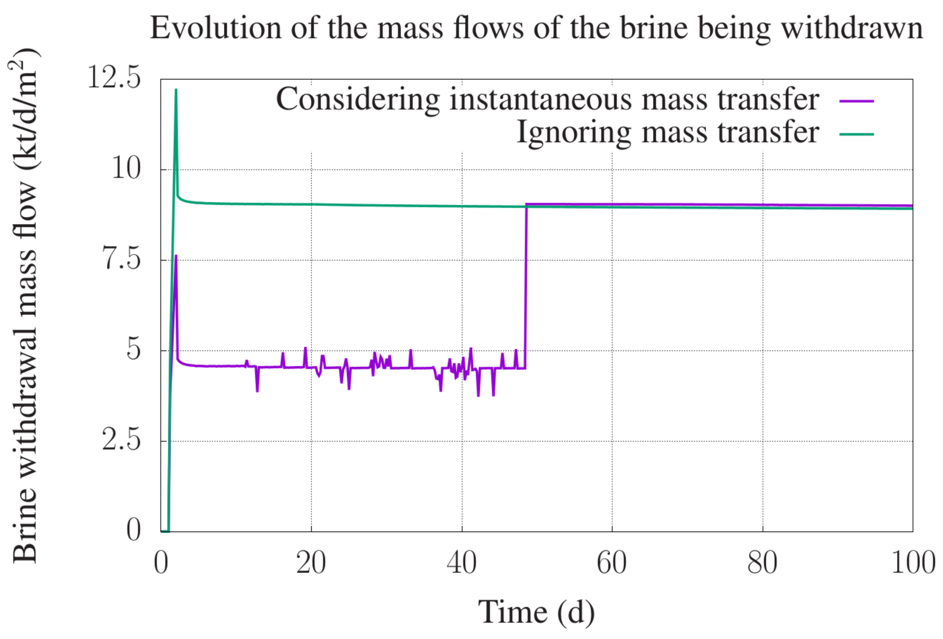
γ-phase $\quad \mathcal{M}_\gamma c_e/t = (c_e^E - c_e)\mathcal{Q}_\lambda^E + (1 - c_e)\pi_e + c_e \pi_n$

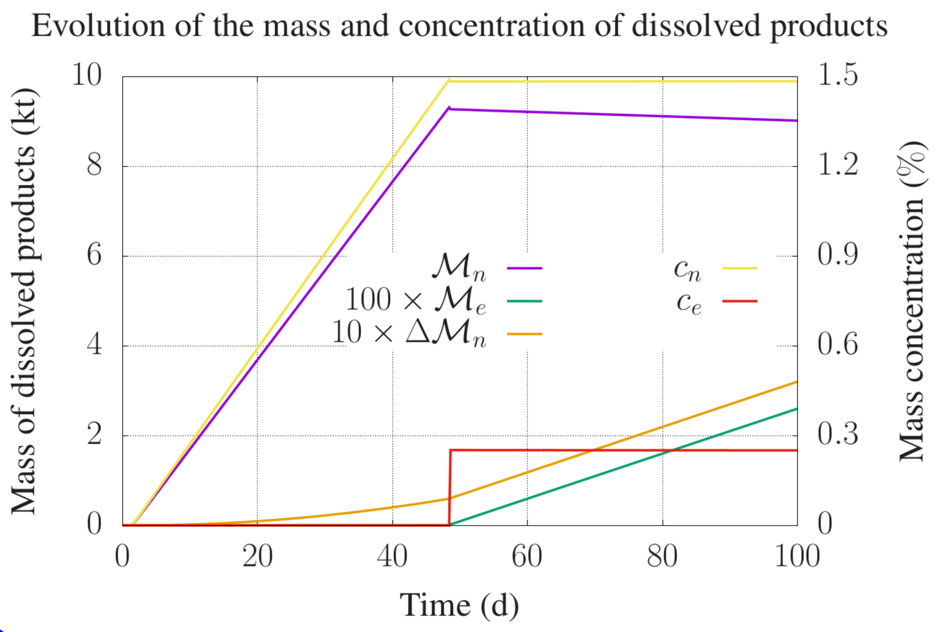
λ-phase $\quad \begin{cases} \mathcal{M}_\lambda c_s/t = (c_s^E - c_s)\mathcal{Q}_\gamma^E + (1 - c_s)\pi_s - c_s(\pi_n - \pi_e) \\ \mathcal{M}_\lambda c_n/t = (c_n^E - c_n)\mathcal{Q}_\gamma^E + (1 - c_n)\pi_n - c_n(\pi_s - \pi_e) \end{cases}$

Impact of the mass transfer on storage behavior?

Simulated CO2 storage behavior considering instantaneous mass transfer

Leaching phase (100 first days)





Complete leaching phase & first storage operations

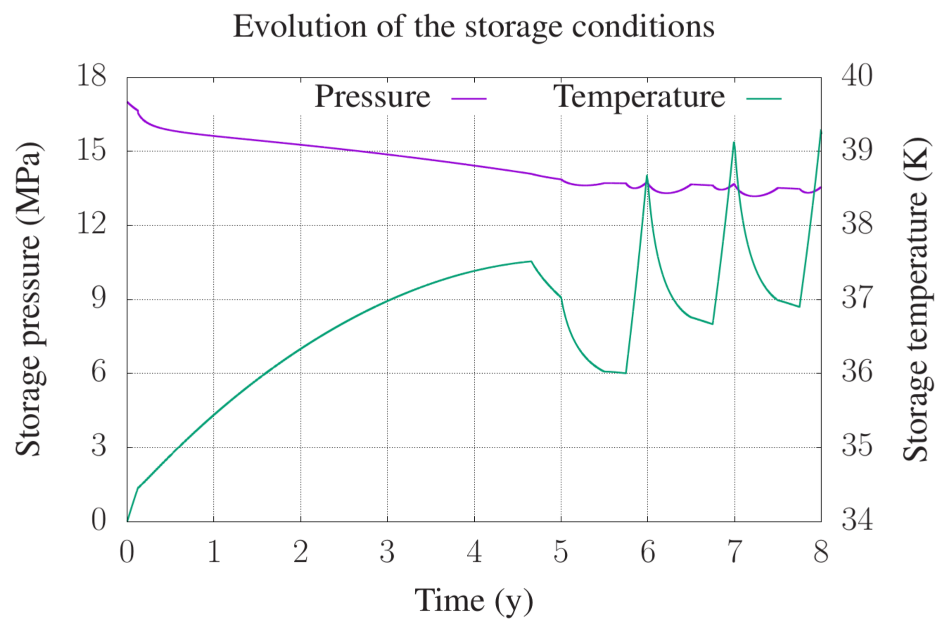
CO2 stored as a liquid: cyclic operations consisting of brine injections and withdrawals

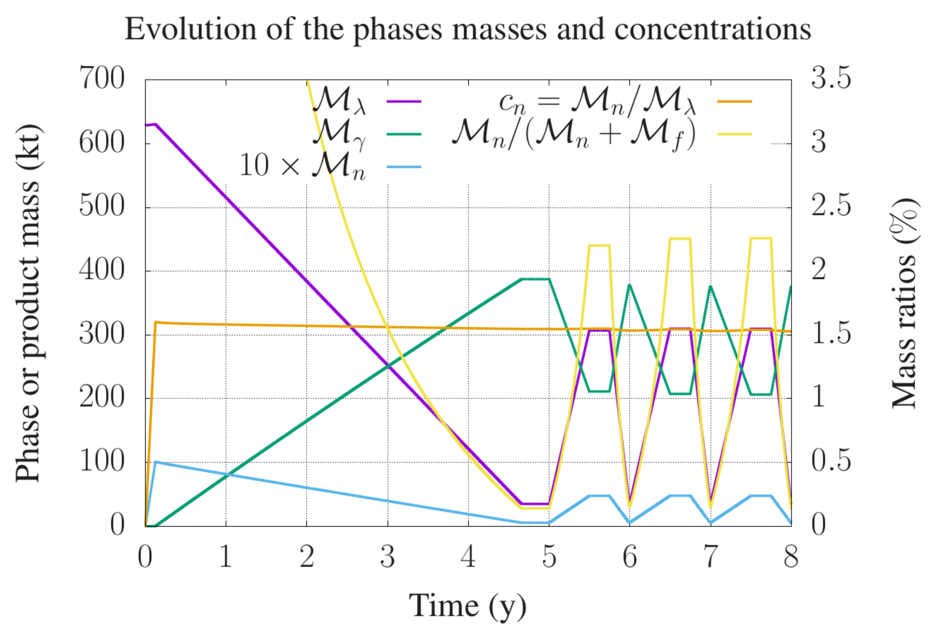
Cumulating losses of fluid during both leaching and operational phases due to the withdrawal of brine containing dissolved gas

Notation subscripts:
- *n* dissolved stored fluid
- *e* evaporated water (humidity)
- *f* non-dissolved stored fluid

50-day period of gas dissolution into the brine to reach saturation

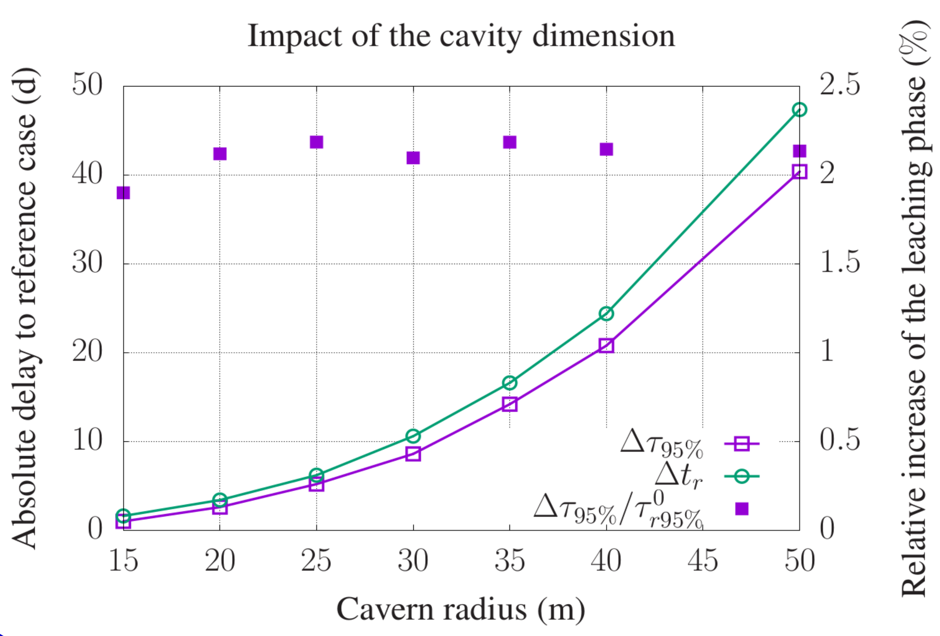
Reduced mass flow for extracted brine during this period - Small influence of the mass transfer then





Parameters involved in the increase of the leaching phase duration considering instantaneous mass transfer

Cavity dimensions



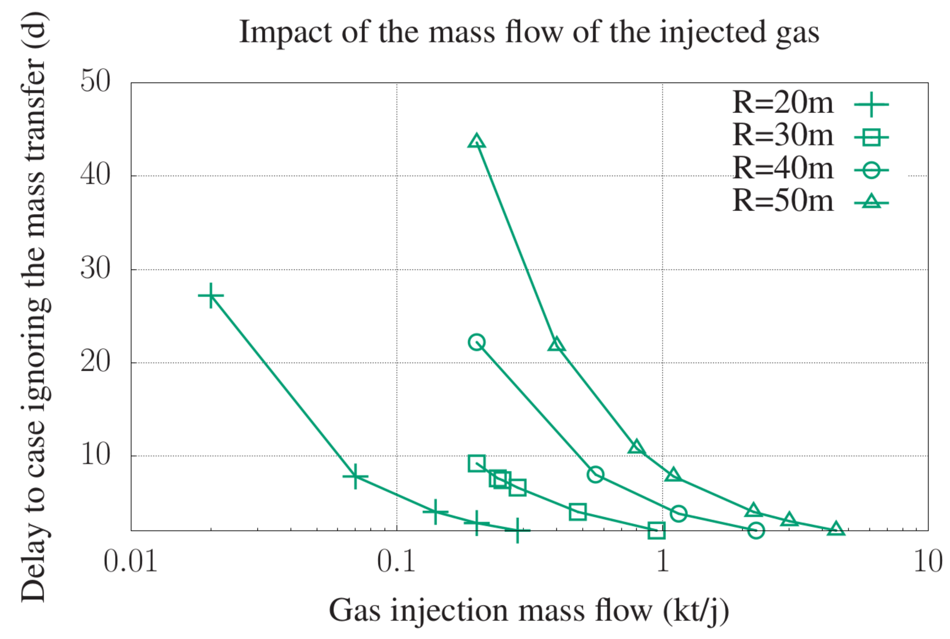
Δt_r Duration of the period of gas dissolution

$\tau^0_{r95\%}$ Leaching phase duration in the reference case ignoring the mass transfer between the both fluid phases

$\Delta\tau_{95\%}$ Additionnal time to withdraw 95 % of the brine volume if gas dissolution is considered, compared to the reference case

Leaching phase extended to about 2 % of its reference duration for a considered cavern volume and injected gas mass flow

Gas mass flow



What about the kinetic of dissolution?

Kinetical aspect of the mass transfer

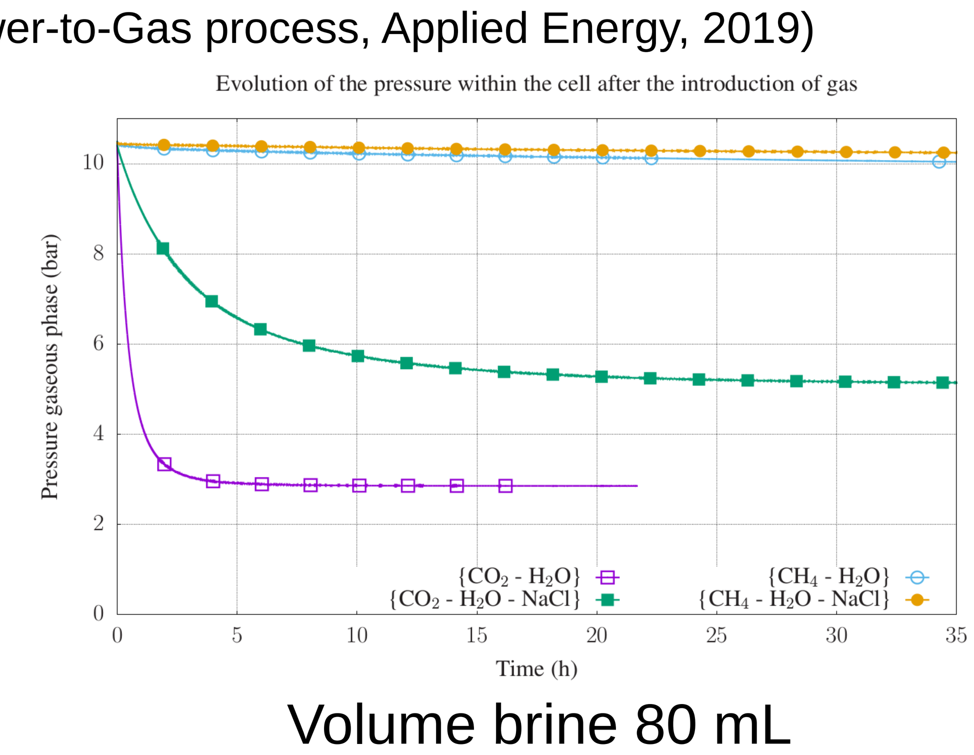
From Soubeyran and al. (Thermodynamic analysis of carbon dioxide storage in salt caverns to improve the Power-to-Gas process, Applied Energy, 2019)

Experimental investigation performed at the laboratory of the Center of Thermodynamics and Processes

Goals:
- To study the evolution with time of the gas dissolution into pure water and salt-brine (depending on the amount of brine)
- To calibrate a kinetic model of the dissolution of gas into brine on the basis of the experimental results

Perspectives: extension of the calibrated model at a salt cavern scale and comparison of the mass transfer rate to the duration of the operations

Volume cell 96 mL



Volume brine 80 mL
Brine salinity 22.5 %