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CENTER FOR SUSTAINABLE FUTURE TECHNOLOGIES

SEASTAR COMPETENCE CENTER

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ScuDo Scuola di Dottorato – Doctoral School
WHAT YOU ARE, TAKES YOU FAR

Experimental Characterization of Thermodynamic Properties of Fluids

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Introduction

Fossil fuels are the main contributor to **Green House Gas (GHG)** emissions in different industrial sectors. The global transition towards a sustainable future has necessitated the exploration of **alternative energy sources** and **storage solutions**. Among the alternative energy and storage solutions, **Underground Hydrogen Storage (UHS)** has emerged as a promising candidate due to its **high energy density** compared to fossil fuels, and **potential for zero-emission applications** .

The **current work** aims to provide an **experimental estimation of the volume of hydrogen** that might dissolve in the aquifer at reservoir conditions (Pressure, Temperature and Salinity). This is essential to estimate the **potential losses** of injected gas into the formation aquifer during and after **UHS** operations. Therefore, a set of experiment was performed at conditions mimicking **real reservoir conditions** currently used to store methane.

State of the art - Solubility

In a **conventional DLE** test performed on an undersaturated oil sample taken from a reservoir, **the solution gas oil ratio is measured directly from the expansion data**. In our problem, **the amount of dissolved gas in water is unknown**, and **it has to be evaluated through a series of experiments**.

The solubility of gas mixtures in brine expressed as **Rsw**, corresponding to the **volume of dissolved gas** at a given **reservoir temperature** and **reservoir pressure**, when **brought to standard conditions** (15°C and 1 bar) **divided by the volume of brine at stock tank conditions**:

$$R_{sw} = \frac{V_{g(p,T)}|_{sc}}{V_w|_{sc}} \quad (1)$$

The **volume ratio of injected gas that dissolves** is:

$$g_s = \frac{\frac{\left(1-S_g\right)V_p}{B_w}\left[R_s\left(p_n\right) - R_s\left(p_o\right)\right]}{\Delta V_{gsc}} = \frac{1}{\frac{S_g\left[\frac{1}{B_g\left(p_n\right)} - \frac{1}{B_g\left(p_o\right)}\right]}{\frac{\left(1-S_g\right)V_p}{B_w}\left[R_s\left(p_n\right) - R_s\left(p_o\right)\right]} + 1} \quad (2)$$

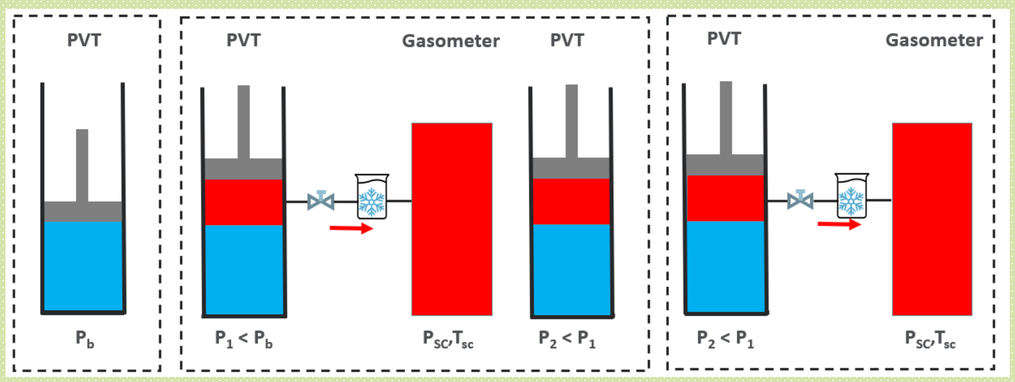
Experimental procedure

PVT analysis is the scientific process used to determine the phase behavior and the properties of fluids such as **hydrocarbons, CO_2 and H_2** at different **thermodynamic** conditions. The PVT characterization is fundamental for production and storage purposes.

PVT cell

Specifications:	
Pressure range	1 to 700 bar
Temperature range	20 to 200 °C
PVT cell volume	300 ml
Visual Volume	300 ml
Accuracy on measurements:	
Pressure	±0.1 bar
Temperature	±0.1°C
Liquid deposit	0.005 ml
Bubble/Dew point repeatability	±0.35 bar
Resisting corrosive abilities	CO_2 and H_2S

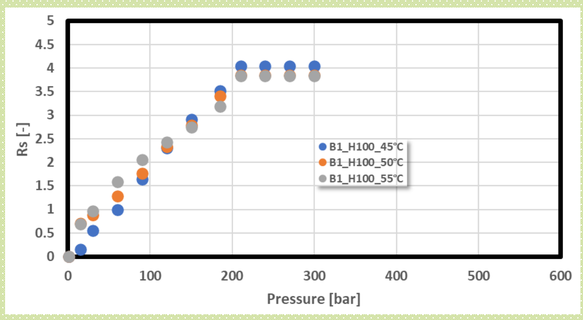
PVT cell is used to compress the hydrogen and the brine solution to reach the working pressure. After complete dissolution of the gas into the brine, the expansion starts, and the **bubble point is recorded** as well as the **volume released at each pressure step**. After release, the **gas** volume **is cooled** with dry ice and is then sent to a **gasometer** as can be seen in the scheme below:

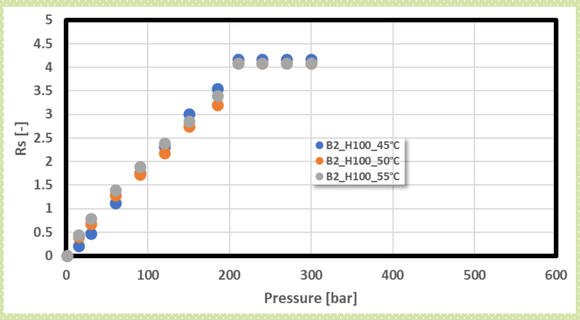


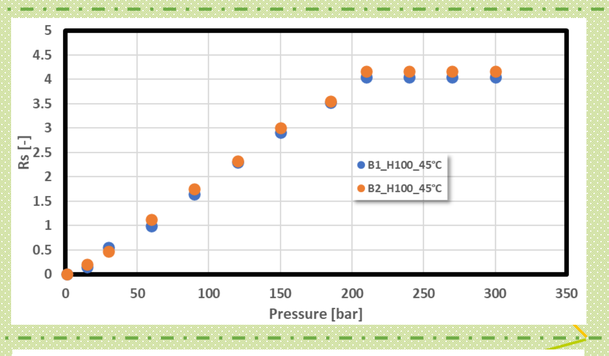
Results

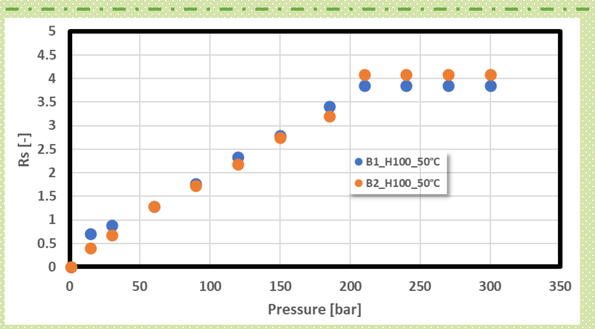
A total of **18 solubility tests** were performed using:
- **Two** different **brine** salinity
- **3** different **gas mixtures** (pure H_2, 50% H_2 / 50% CH_4, 10%H_2 / 90% CH_4)
- **3** different **temperatures** (45, 50 and 55°C)

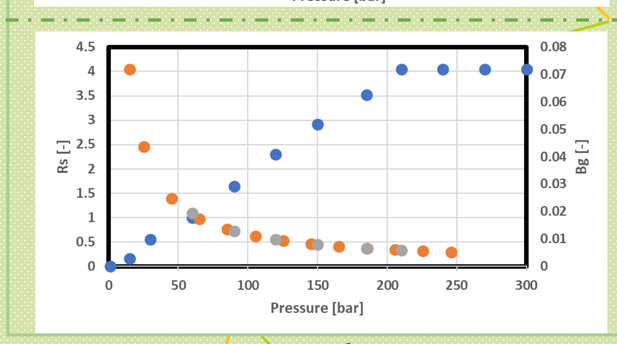
					Gasmeter data			
Test #	Gas	Brine	T [°C]	P_{max} [bar]	$V_{H2,CH4}$ [nml] cumulative	Gasometer T [°C]	Rsw_{max}	Estimated Pb [bar] (during expansion)
1	100 H_2	B1	45	300		25		
2		B1	50	300		21		
3		B1	55	300		21		
4		B2	45	300		26		
5		B2	50	300		22		
6		B2	55	300		22		
7	50% H_2, 50% CH_4	B1	45	350		23		
8		B1	50	350		23		
9		B1	55	400		24		
10		B2	45	350		23		
11		B2	50	350		25		
12		B2	55	400		24		
13	10% H_2, 90% CH_4	B1	45	500		24.8		
14		B1	50	500		26.8		
15		B1	55	500		26.2		
16		B2	45	500		25.3		
17		B2	50	500		26		
18		B2	55	500		25.1		

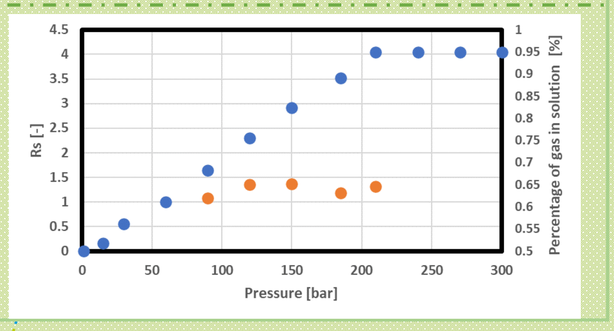












Conclusion

- At the **experiment conditions**, the **impact of the differences in the composition of the two analyzed brines** as well as the impact of the analyzed range of temperatures were **not significant**.
- The obtained **solubility** results might represent an overestimation of dissolved gas at reservoir conditions due to the assisted stirring during compression. It is also important to point out that within the reservoir, the **direct contact area** between the **gas and the brine is smaller** compared to the **PVT** cell.
- Thus, at reservoir conditions the possible **losses due to dissolution** in reservoir brine should be **extremely low**.