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Phase equilibria and densities of multi-component CO_2 mixtures , systems of relevance to CCS

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Project sponsors and partners

- UKCCSRC Call 1 (£100k, 2013-2014)
- UKCCSRC Call 2 (£162k, 2014-2016)
- EPSRC
- ETI
- TSB

- National Grid
- E.ON
- Rolls-Royce
- PSE

Prof. Michael W. George

- Collaborators from the COZOC, MATTRAN and COOLTRANS projects

Vapour-liquid-equilibrium and density

- CO_2 compressor and pump design
- Flow rate monitoring
- Pipeline transport of CO_2

Impurity in CO_2 streams: N_2, H_2, Ar, H_2O, CH_4, CO, H_2S and etc.

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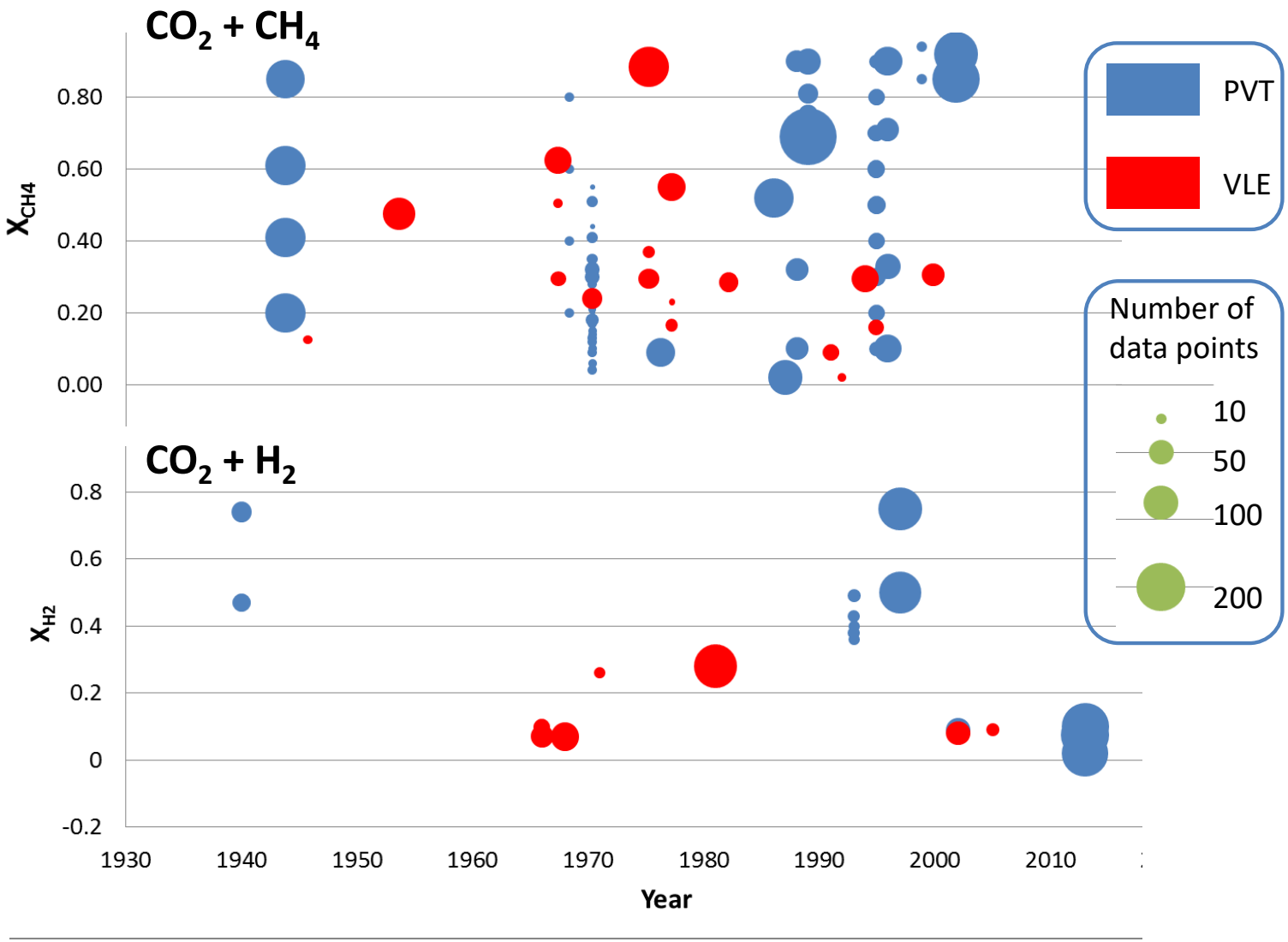
Expansion of the database of the CO_2 mixtures relevant to CCS



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Ternary and quaternary CO_2 mixtures

CO_2 + impurities	Type of property	Data range			Data points	References
		T/K	p/MPa	x_{CO2}		
N_2 + O_2	VLE	218-273	5.2-11	0.15-0.92	64	(Zenner and Dana, 1963)
	VLE	273	5.2-11	0.60-0.96	12	(Muirbrook and Prausnitz, 1965)
N_2 + Ar	density	323-423	3-31	0.90-0.95	132	(Yang et al., 2015b)
N_2 + CH_4	VLE	233-273	6.1-10	0.25-0.95	53	(Sarashina et al., 1971b)
	VLE	270	4.6-11	0.56-0.98	48	(Somait and Kidnay, 1978)
	VLE	220-250	6.1-12	0.15-0.89	88	(Al-Sahhaf, 1990; Al-Sahhaf et al., 1983)
	VLE	293-298	6.0-8.3	0.86-0.99	80	(Xu et al., 1992a, b)
	density	323-573	20-100	0.1-0.8	271	(Seitz et al., 1996)
Ar + O_2	VLE	253-293	2.3-7.6	0.54-0.99	28	(Coquelet et al., 2014)
H_2 + CO	VLE	233-283	5.1-20	0.53-0.98	31	(Kaminishi et al., 1968)
	VLE	254-302	4.0-8.8	0.97-0.99	52	(Yokoyama et al., 1988)
	VLE	282-303	8.4-14	0.71-0.96	15	(Ke et al., 2001)
	(critical point)					
N_2 + O_2 + Ar	VLE	253-293	7.1-9.0	0.90	4	(Chapoy et al., 2013b)
	density	273-423	1-125	0.90	43	(Chapoy et al., 2013b)
CH_4 + H_2O	VLE	298-323	6.2-13.8	0.9469	21	(Song et al., 1990)

Contents

- High pressure facilities for measuring the phase equilibrium and density of multi-component CO_2 mixtures
- Solubility of water in impure CO_2
- New VLE and density data of the binary/ternary mixtures of CO_2, N_2, H_2 and Ar
- Validation of the equations of state using the new data

Int. J. Greenh. Gas Control **2013**, *13*, 78. *Rev. Sci. Instru.* **2014**, *85*, 085110. *Int. J. Greenh. Gas Control* **2015**, *35*, 131. *Int. J. Greenh. Gas Control* **2015**, *41*, 68. *J. Chem. Thermodyn.* **2016**, *93*, 386. *Int. J. Greenh. Gas Control* **2017**, *56*, 55.

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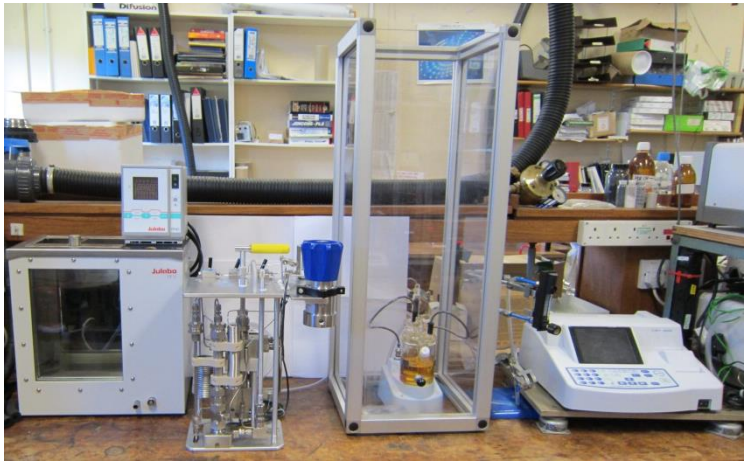
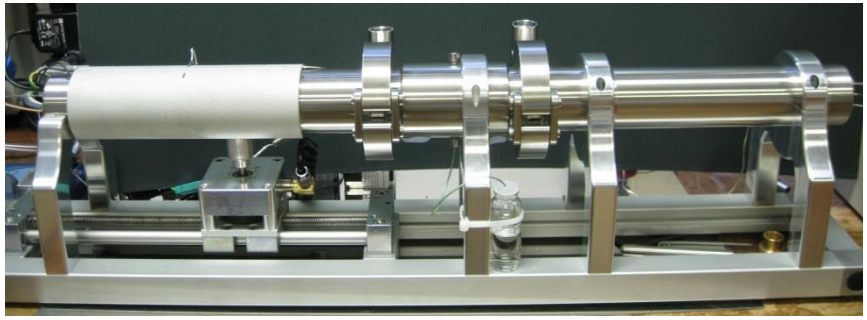
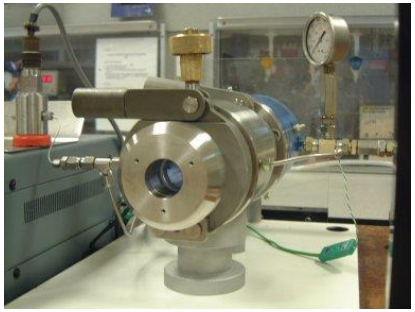
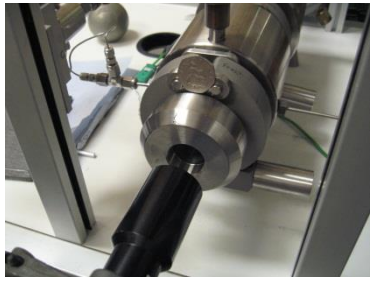
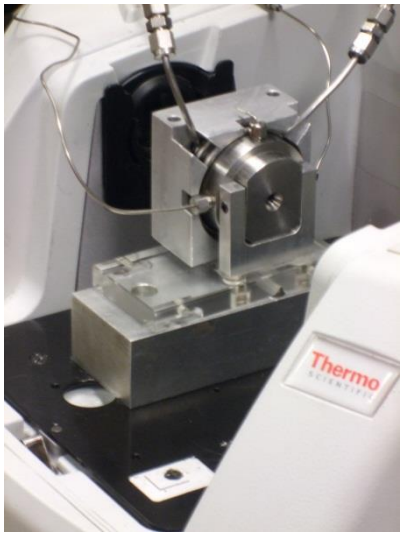
High-pressure facilities in Nottingham



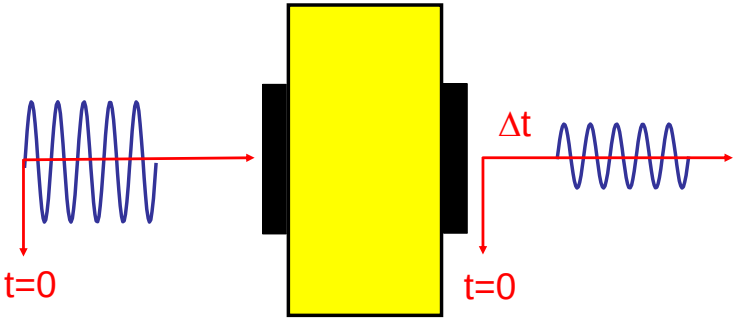


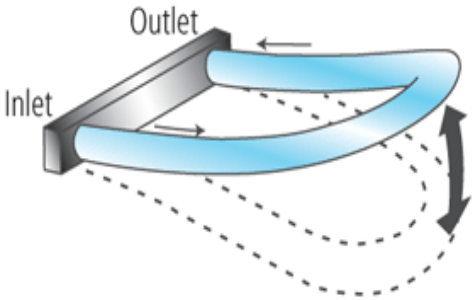


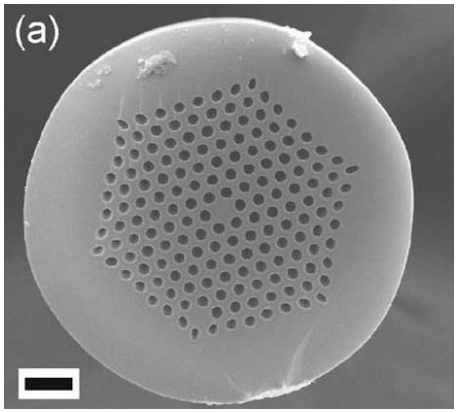


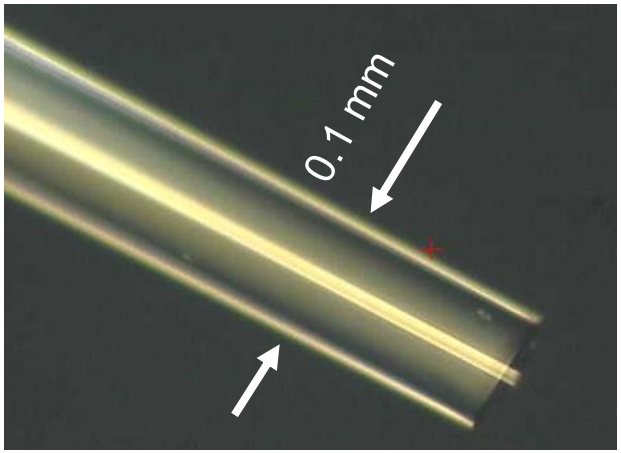


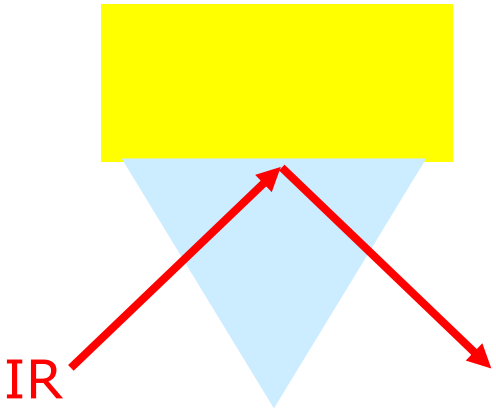
Sensors

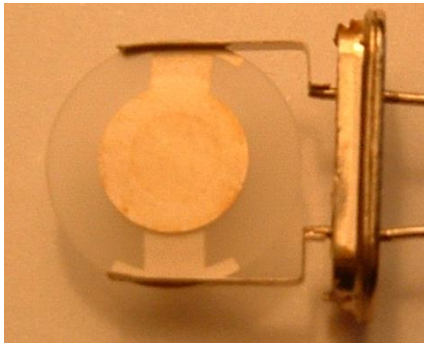












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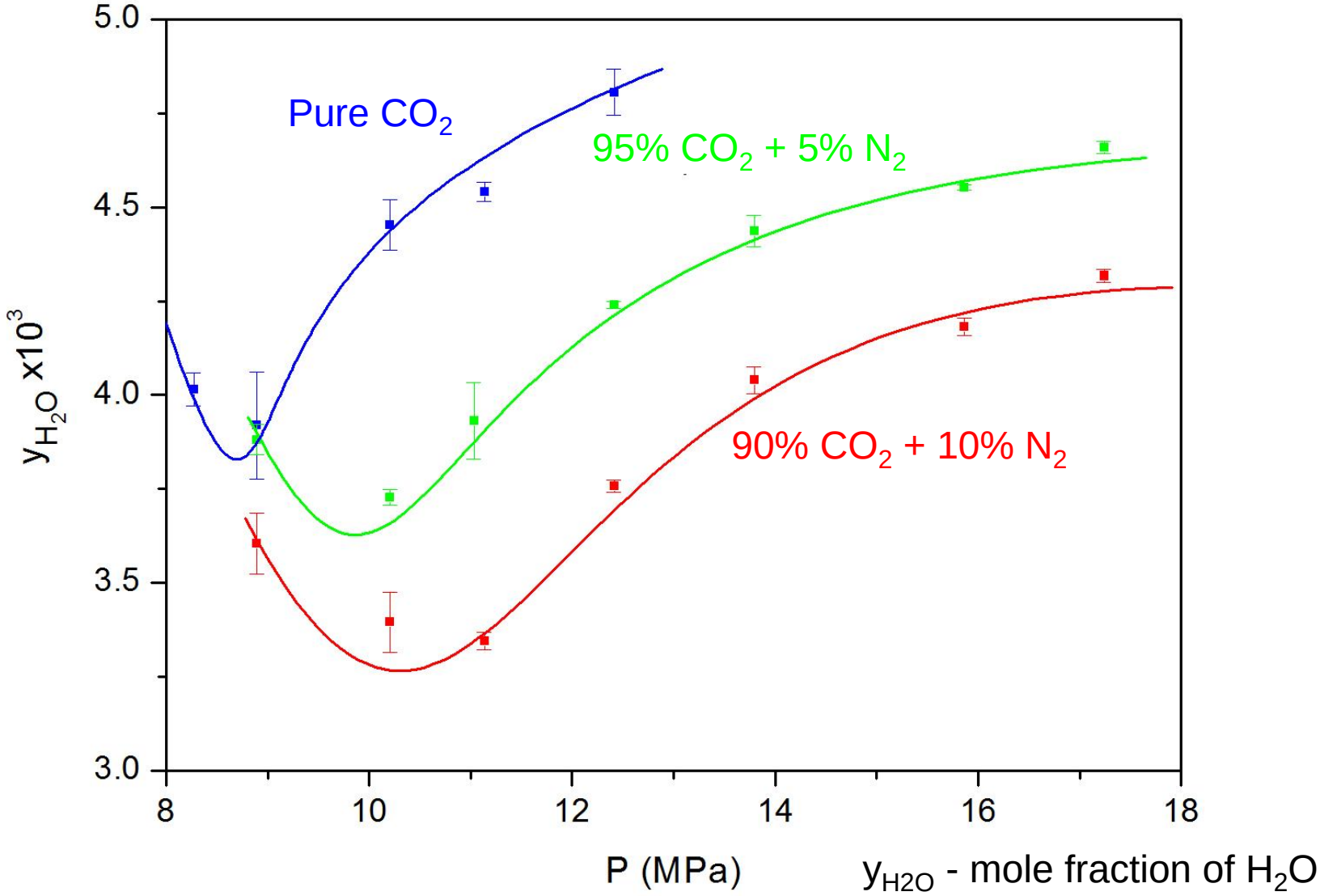
Solubility of H_2O in CO_2 + N_2 (40 °C)



y_{H2O} - mole fraction of H_2O

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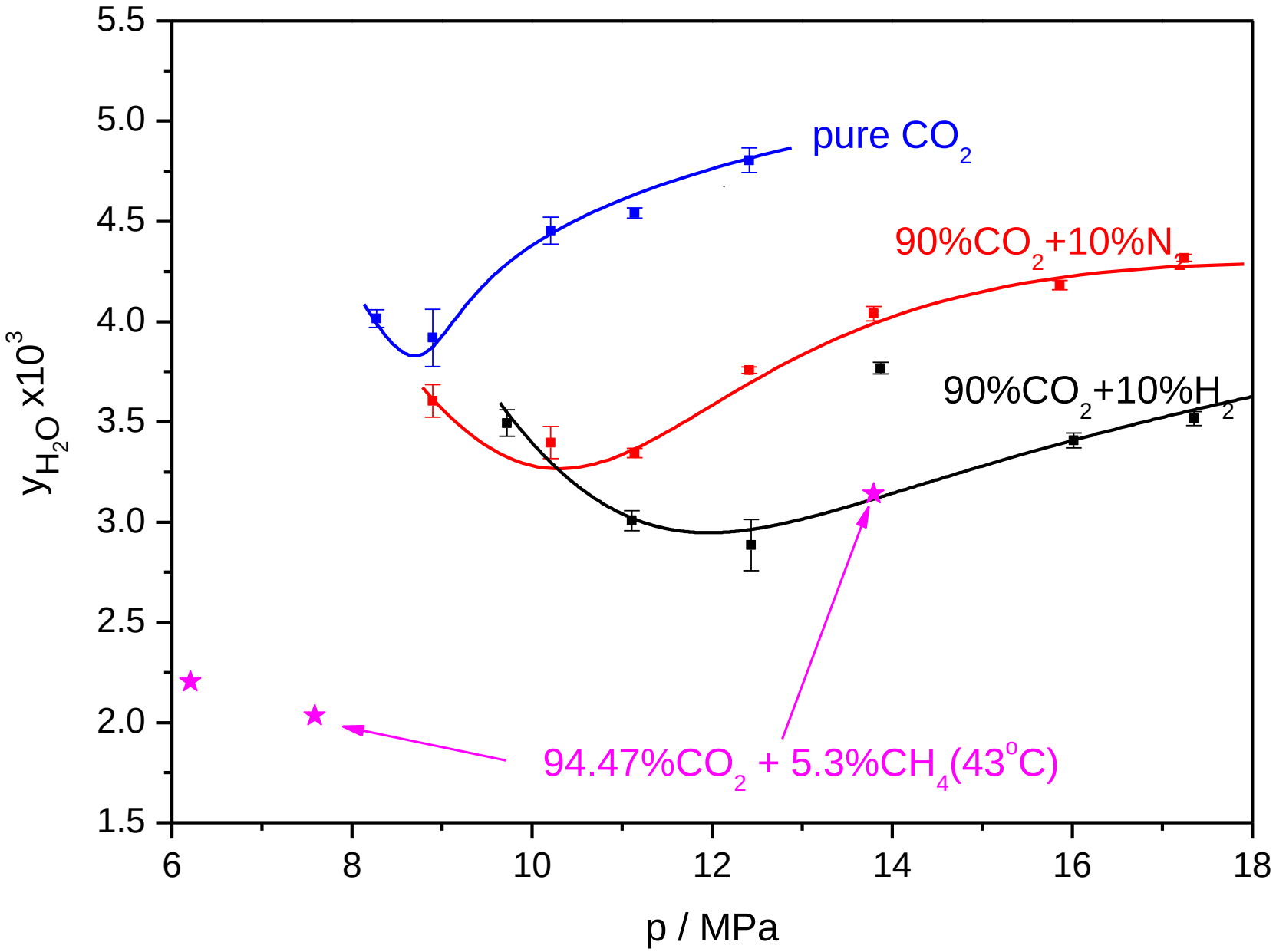
Solubility of H_2O in CO_2 with different impurities (40 °C)



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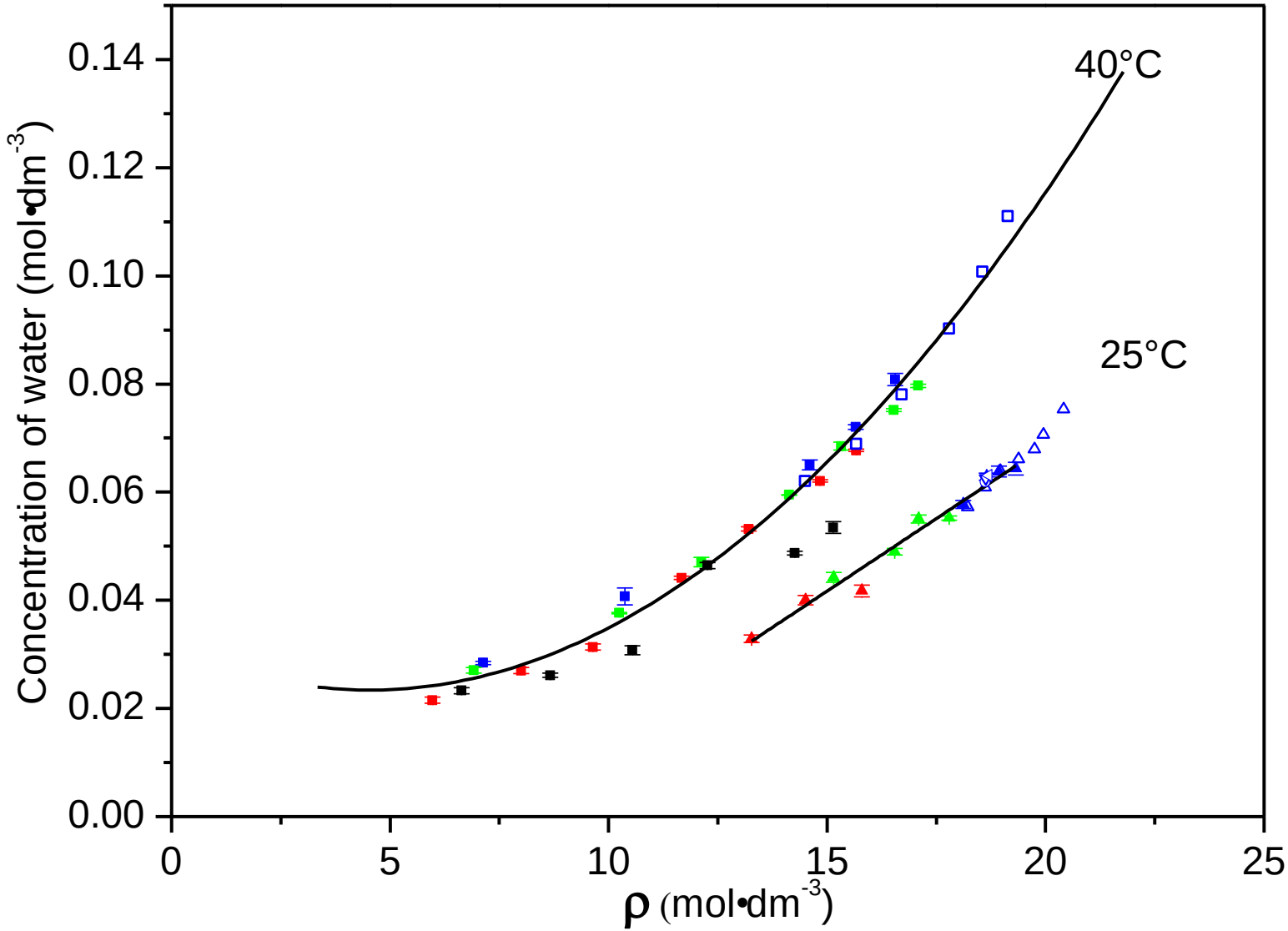
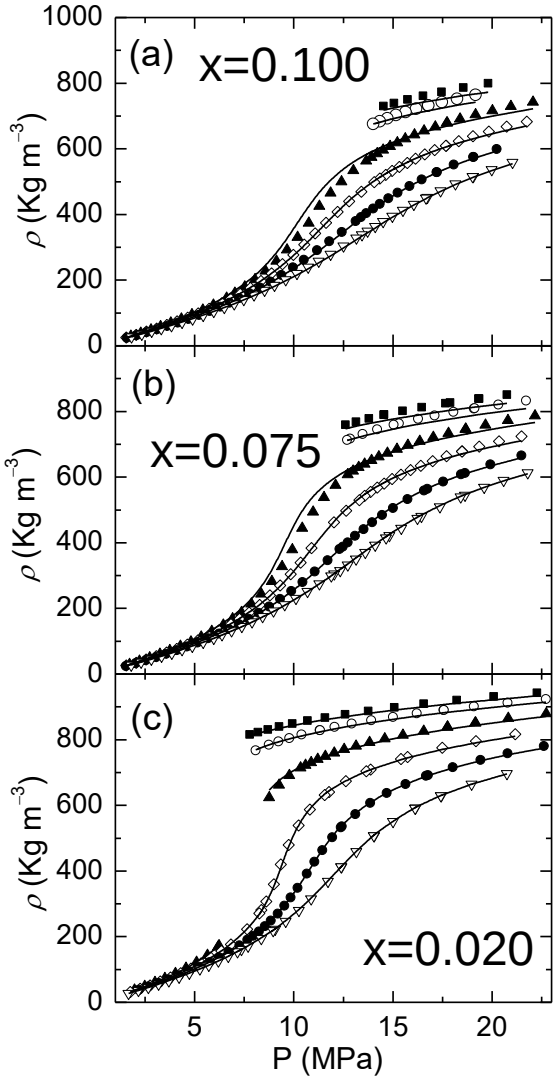
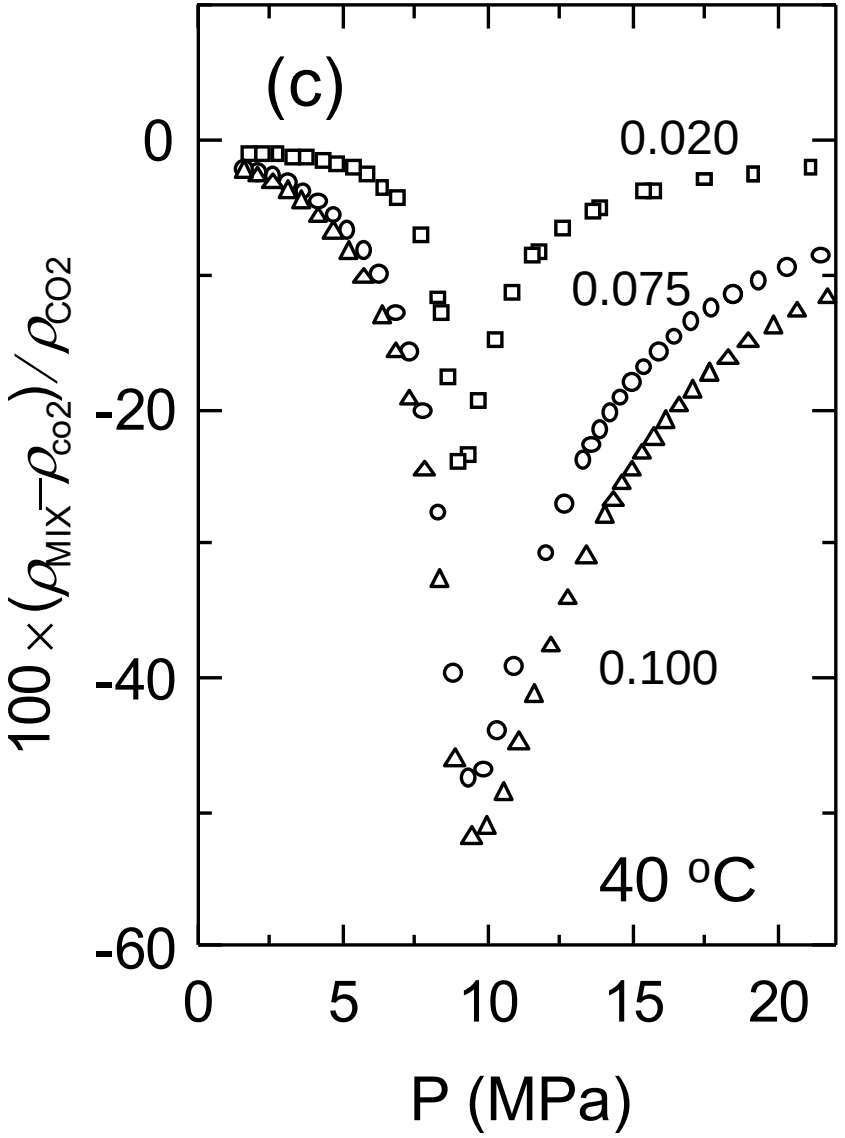
Density effect on the solubility of H_2O in CO_2 with and without impurities (25 °C and 40 °C)



Density of $(1-x)CO_2 + xH_2$ between 15 and 60 °C





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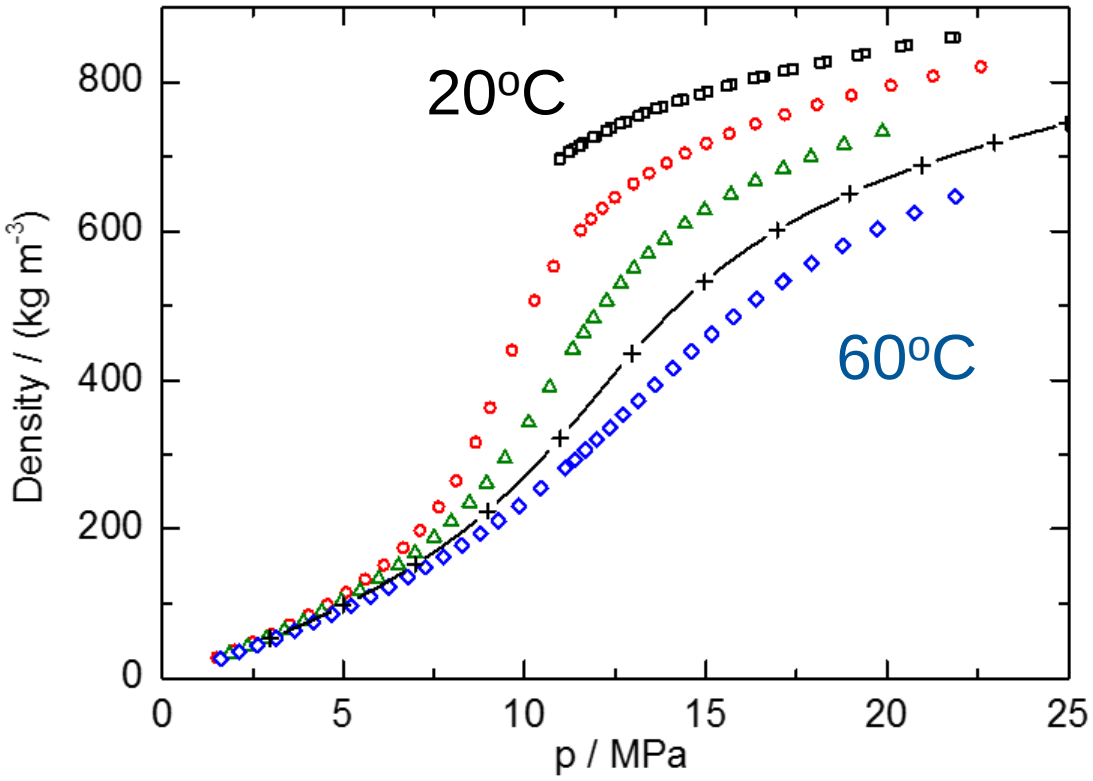
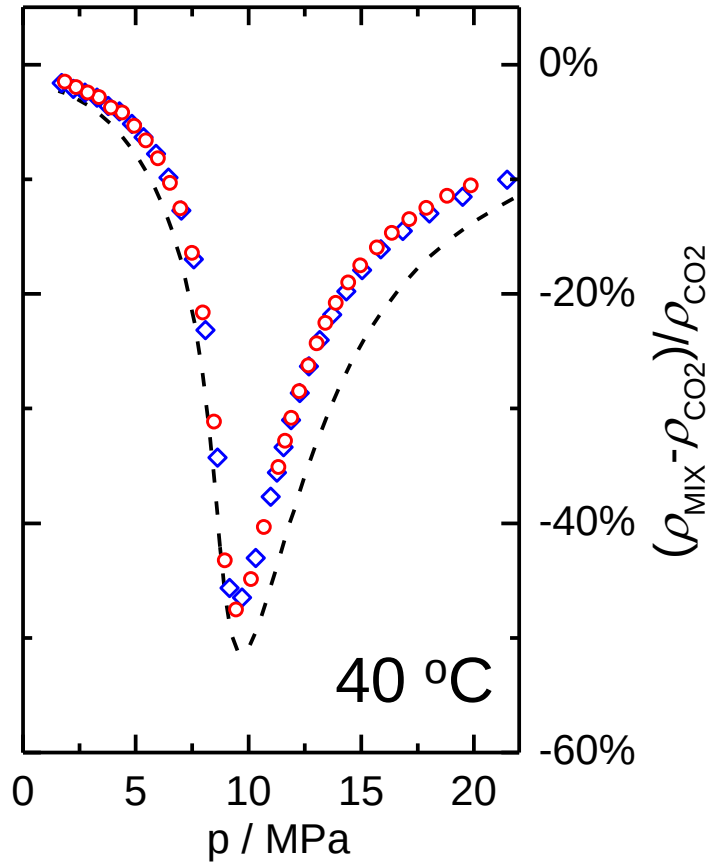
Density of $0.90CO_2 + 0.05Ar + 0.05N_2$ between 20 and 60 °C





○ **$90\%CO_2 + 5\%Ar + 5\%N_2$**

◇ **$90\%CO_2 + 10\%N_2$**

– – **$90\%CO_2 + 10\%H_2$**