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CO_2 and H_2S Capture with Deep Eutectic Solvents

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My first GCC-EU collaboration

- European (7th framework) project '**IOLICAP**': Novel IOnic LIquid and supported ionic liquid solvents for reversible CAPture of CO_2 (and H_2S)
- Project partners:

A2: List of Beneficiaries

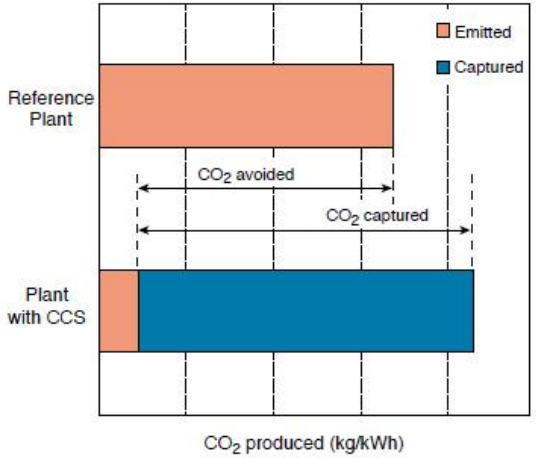
Project Number [1]	283077	Project Acronym [2]	IOLICAP

List of Beneficiaries

No	Name	Short name	Country	Project entry month [10]	Project exit month
1	NATIONAL CENTER FOR SCIENTIFIC RESEARCH "DEMOKRITOS"	NCSRD	Greece	1	36
2	FRIEDRICH-ALEXANDER-UNIVERSITAT ERLANGEN NURNBERG	FAU	Germany	1	36
3	SCIENOMICS SARL	SC	France	1	36
4	IOLITEC IONIC LIQUIDS TECHNOLOGIES GMBH	IT	Germany	1	36
5	THE UNIVERSITY OF MANCHESTER	UM	United Kingdom	1	36
6	TECHNISCHE UNIVERSITEIT EINDHOVEN	TU/e	Netherlands	1	36
7	PUBLIC POWER CORPORATION S.A.	PPC	Greece	1	36
8	N & K KONSTANTINOS GOLIOPOULOS ATE	N.C.G	Greece	1	36
9	THE PETROLEUM INSTITUTE	PI-ADNOC	United Arab Emirates	1	36
10	ENDITECH ANONYMOS ETERIA MELETES KE EFARMOGES	NDTech	Greece	1	36

Aim of the collaboration

- Improve the current pre/post-combustion capture technology:
  - Reducing the parasitic energy load
  - Higher absorption/stripping rates
  - Lower viscosity
  - Confronting the problem of solvent degradation and volatility



Loss of power plant efficiency due to CSS = 11 to 22%

Major point source emitters

60% of CO_2 emissions
- Power plants
- Large scale industries

CO_2 Capture
$37 < US\$/tCO_2 < 74$

Transportation
$0 < US\$/tCO_2 < 5$

Sequestration
$0.6 < US\$/tCO_2 < 8.3$

Source: IPCC, CCS special report (2005)

Key objectives of the collaboration

Development and evaluation of novel task specific low-volatile solvents (ILs and DES)

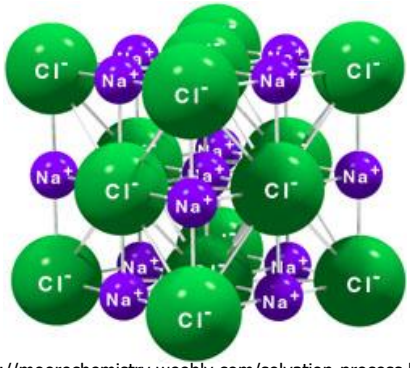
(a) Short-term
could replace the conventional solvents

(b) Long-term
establishment of a novel CO_2 capture process, based on hybrid absorption/membrane technology

Ionic liquids

Molten salt

Na^+ Cl^-

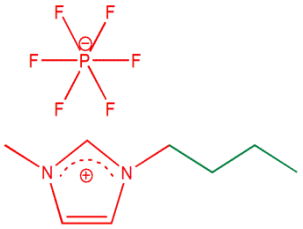


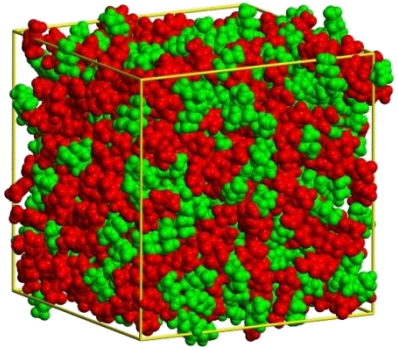
http://moorechemistry.weebly.com/solvation-process.html

T_m = 801 °C

P^{sat} = 0

Ionic liquid



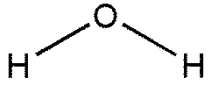


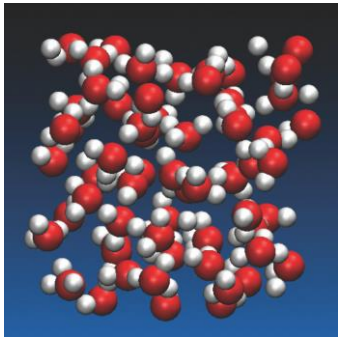
J. Phys. Chem. B 2006, 110, 3330-3335

T_g = −94 °C

P^{sat} = 0

Molecular liquid





J. Chem. Phys. 2014, 141, 064501

T_m = 0 °C

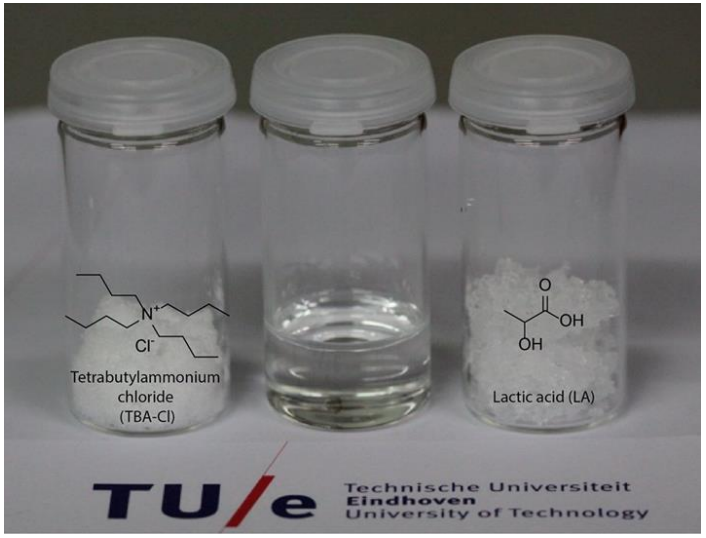
P^{sat} = 31 mbar at 25 °C

Ionic → **Non-Ionic**

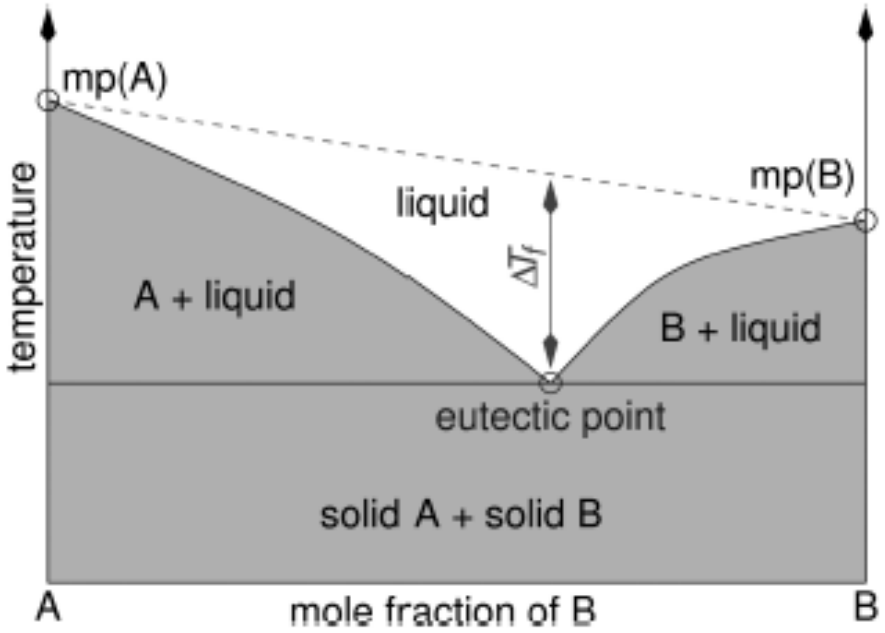
Deep eutectic solvents

TBA-Cl
(T_m = 70°C)

LA
(T_m = 53°C)



TBA-Cl : LA (1:2)
T_g = -66°C

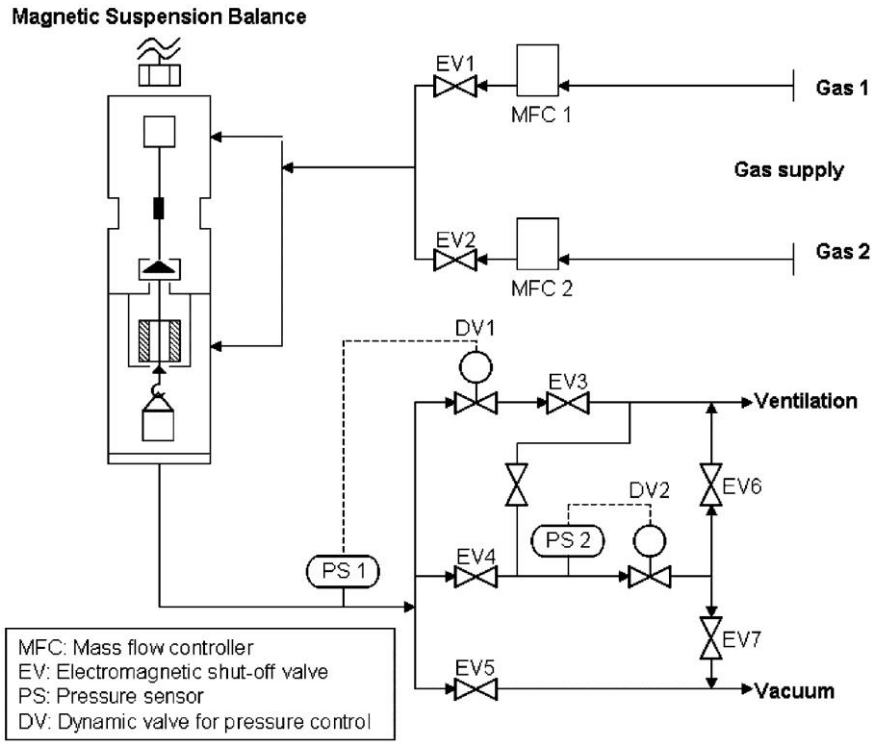


Liquid formation upon mixing
(T_m far below the individual components)

(*Chem. Rev.* 2014, 114, 11060−11082)

Determining CO_2 and H_2S solubilities and diffusivities

- Magnetic suspension balance (Rubotherm):
  - CO_2 absorption isotherms
  - CO2 diffusion coefficients
  - High Pressure Gravimetrical Analysis
  - Mixtures of Gases
  - Special design for liquid samples
  - (273< T/K <423, P/MPa <15)
  - Resolution: 0.01 mg

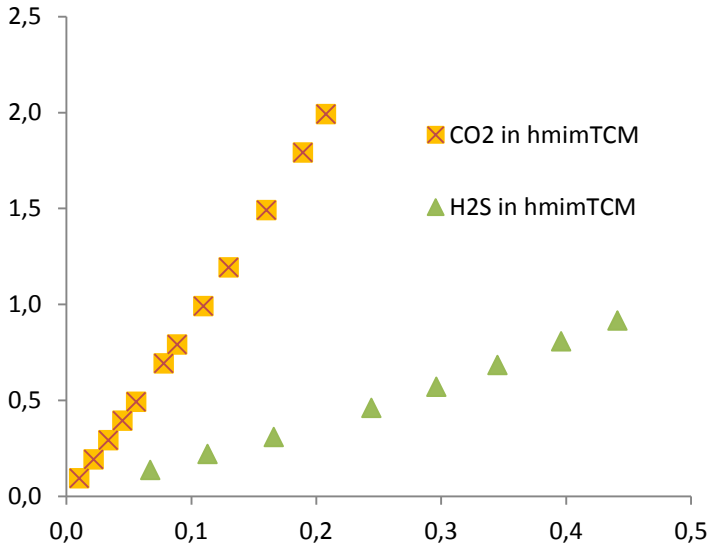


A schematic representation of the MSB

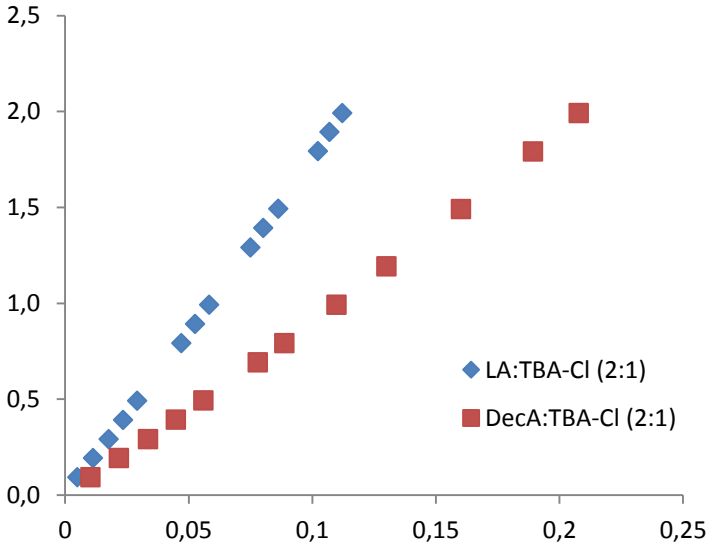
Results and discussion

- CO_2 and H_2S solubilities

in ionic liquids:



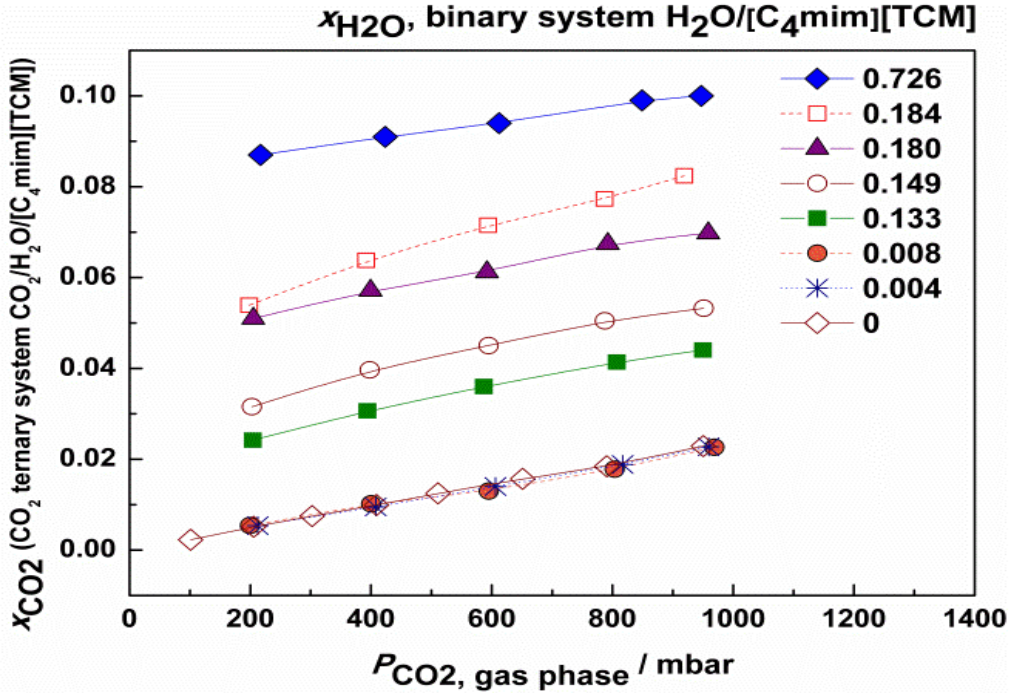
in deep eutectic solvents:



Results and discussion

- Effect of water addition on absorption capacity and rate:

Higher absorption/ stripping rates



***D* of CO_2 in dry and hybrid [C_4mim][TCM]/H_2O**

x_{H_2O}	0	0.149
***P*/Pa(x10²)**	***D*/m²·s⁻¹**	***D*/m²·s⁻¹**
400-600	$8.0 \cdot 10^{-11}$	$1.22 \cdot 10^{-9}$
600-800	$7.3 \cdot 10^{-11}$	$1.82 \cdot 10^{-9}$

Results and discussion

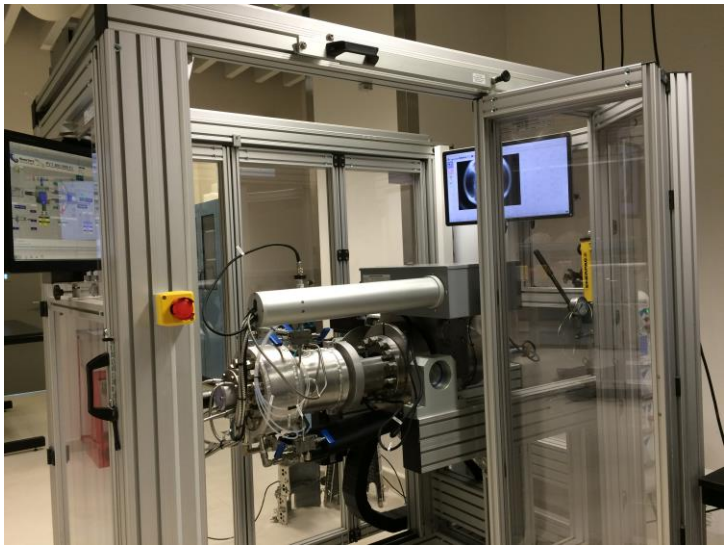
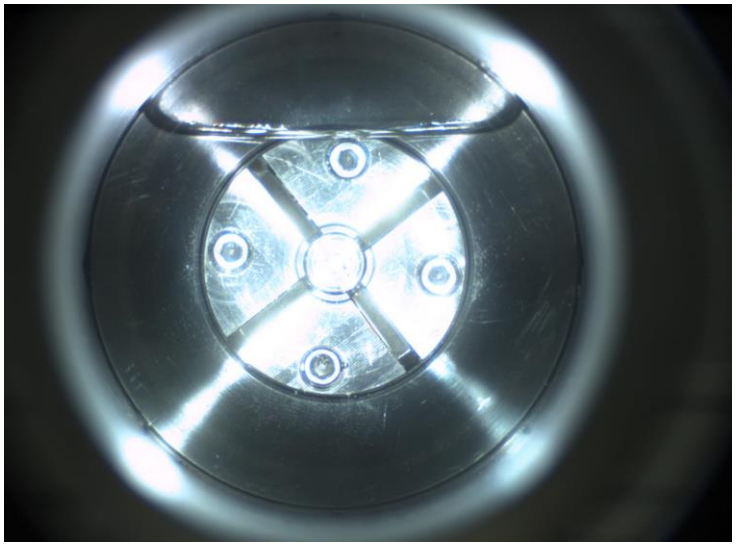
- Thermodynamic analysis:

Henry's constant and heat of absorption

Solvent	C_n	H/MPa (T=308K)	Δh_{sol}^{∞}/kJ·mol^{-1} (x_{CO2} = 0.1)
[C_2mim][TCM]	2	6.70 ± 0.07	-13.7 ± 0.3
[C_4mim][TCM]	4	6.02 ± 0.06	-13.9 ± 0.2
[C_6mim][TCM]	6	5.55 ± 0.12	-13.7 ± 0.03
[C_8mim][TCM]	8	5.12 ± 0.06	-13.5 ± 0.1
Selexol		4.37[1]	(-14.3)[1] (-16.4)[2]
MEA(30%)			-82[3]

Reducing the parasitic energy load

1: Xu *et al.* *Canad. J. Chem. Eng.* 1992, 70, 569-573
2: Korens *et al.* SFA Pacific for U.S. Department of Energy, Mountain View, 2002
3: Carson,J. K. *et al. J. Chem. Thermodyn.* 2000, *32*, 1285–1296

Conclusions

- Aqueous mixtures of ionic liquids or deep eutectic solvents are potential replacements for conventional gas sweetening solvents
- PI/Abu Dhabi interested in application
- Since this year, we can also do measurements in the new thermodynamic fluids lab at PIRC