Universitat d'Alacant
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Novel carbon nanomaterials for selective CO_2 capture

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Universitat d'Alacant
Universidad de Alicante

LMA Laboratorio de Materiales Avanzados

INSTITUTO UNIVERSITARIO DE MATERIALES DE ALICANTE

✓ *Introduction*

Carbon Dioxide Pollution

CO_2 is a greenhouse gas which is a major contributor to global warming

Main Source

Combustion of fossil fuel (coal, oil, gas in power plants, automobiles and industrial facilities)

✓ *Introduction*

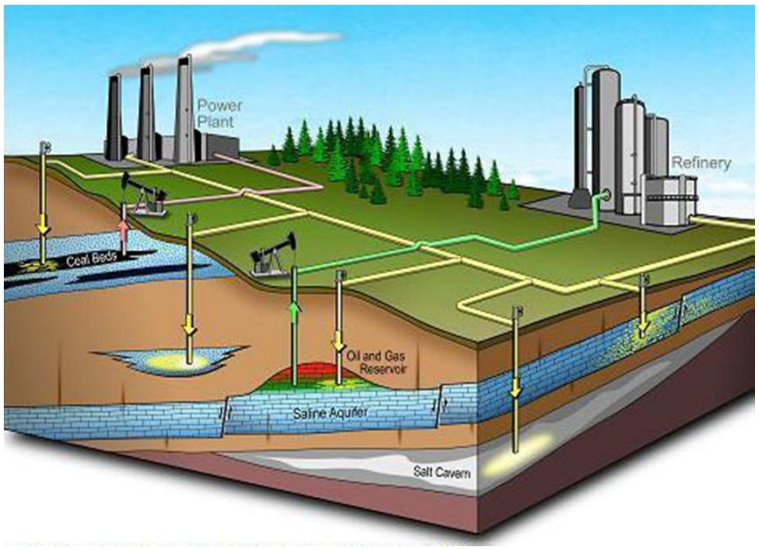
Carbon Dioxide Solutions

- Carbon Dioxide Sequestration (e.g. injection into deep underground reservoirs)

Requirements

Capture and concentration of CO_2 from large emission sources, such as power plants

!!!!CO_2 is accompanied by other gases: N_2, O_2, H_2O, NO_x, SO_x, particulate!!!!



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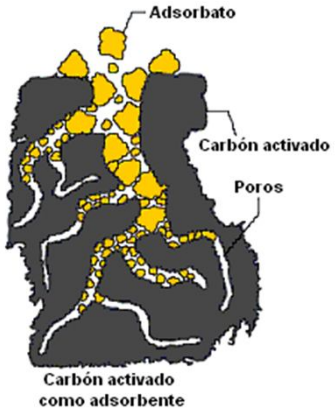
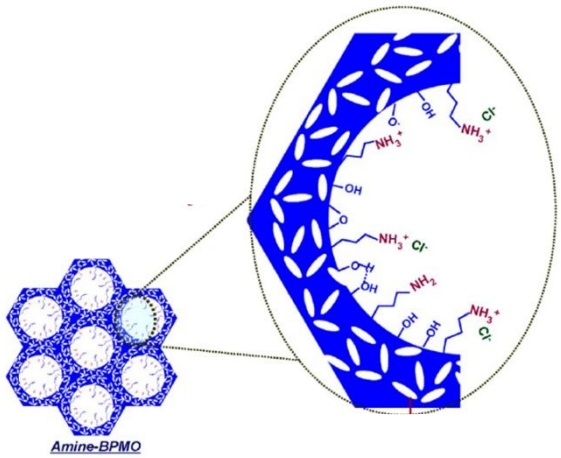
Selective CO_2 capture

Porous Structure

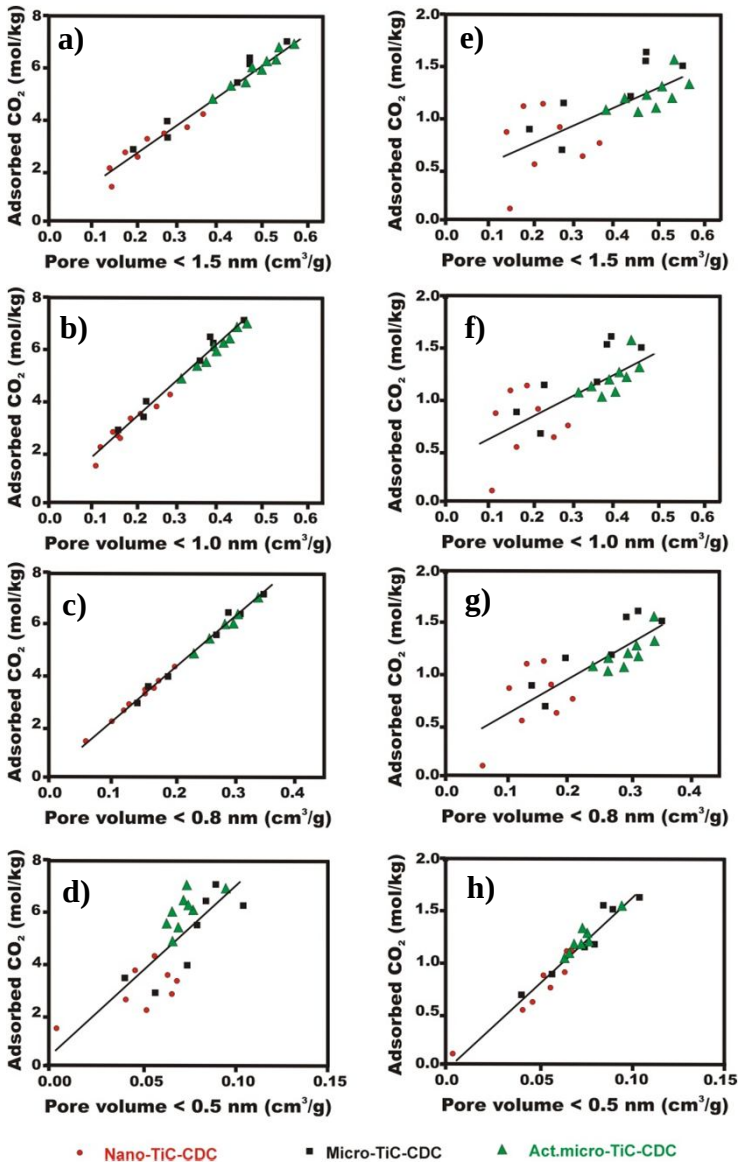


Surface Chemistry



✓ Introduction

Effect of pore size



TiC-CDC
T=273K

(a-d) 1 bar
(e-h) 0.1 bar

Presser et al. Energy & Environ. Sci. 4, 3059-3066 (2011)

✓ *Introduction*

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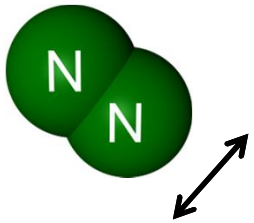
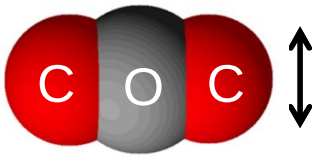
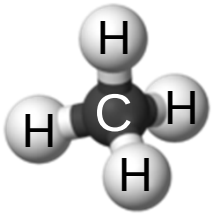


0.36 nm



0.33 nm



0.39 nm

✓ *Introduction*

Molecular Sieves

Microporous solids with a very narrow pore size distribution, the dimension of micropores being similar to the molecules to be adsorbed/separated.

Molecular discrimination caused by:

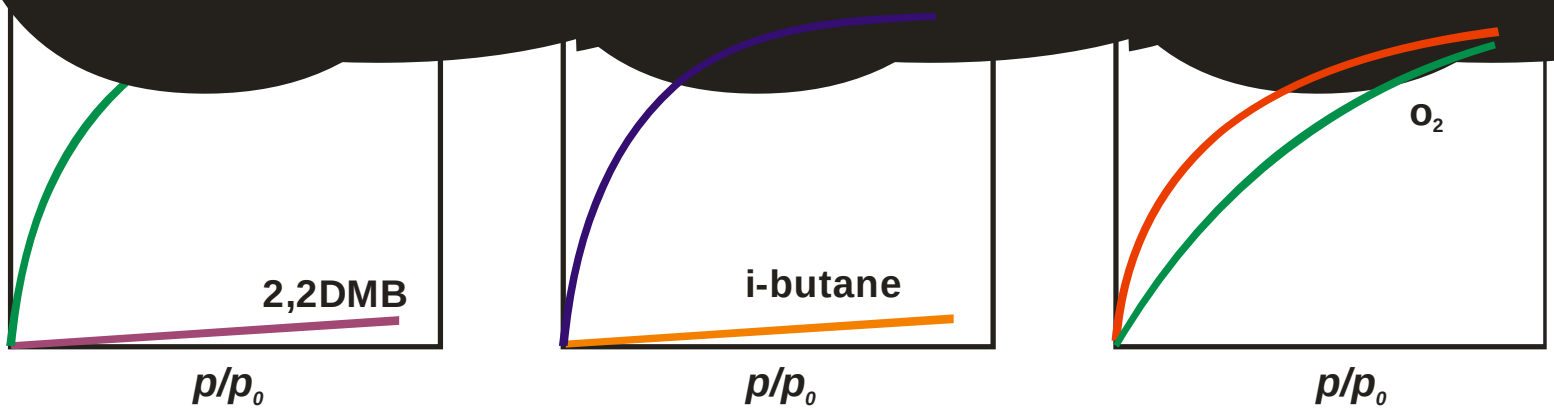
- molecular dimension
- molecular shape
- kinetics of adsorption

✓ *Introduction*

Molecular Sieves

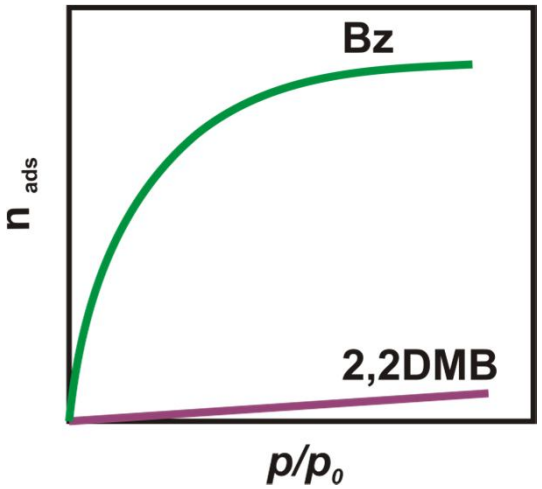
✓ *Introduction*

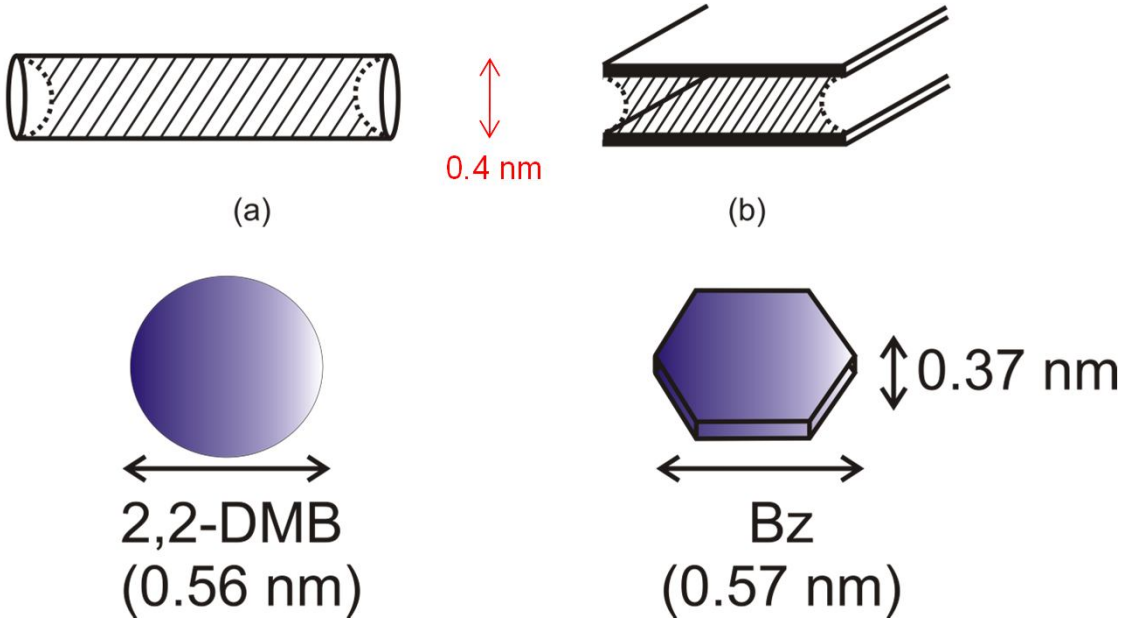
Molecular Sieves: Equilibrium adsorption isotherms



✓ *Introduction*

Selectivity by molecular shape





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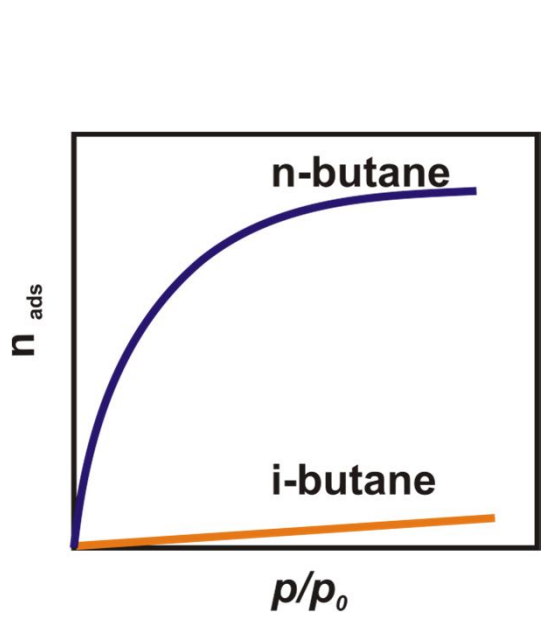
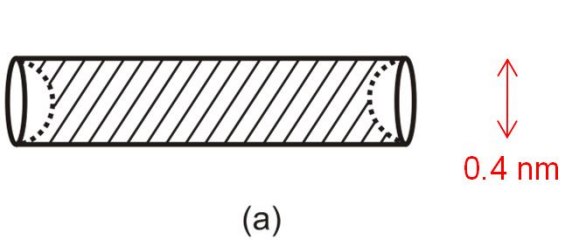
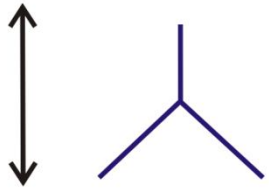
Selectivity by molecular size





n-butane
(0.43 nm)



i-butane
(0.56 nm)

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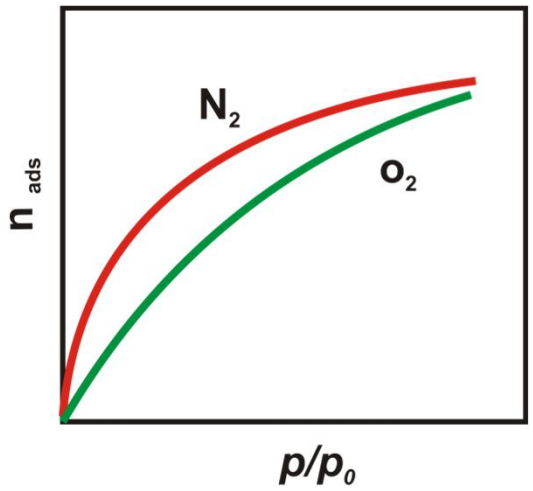
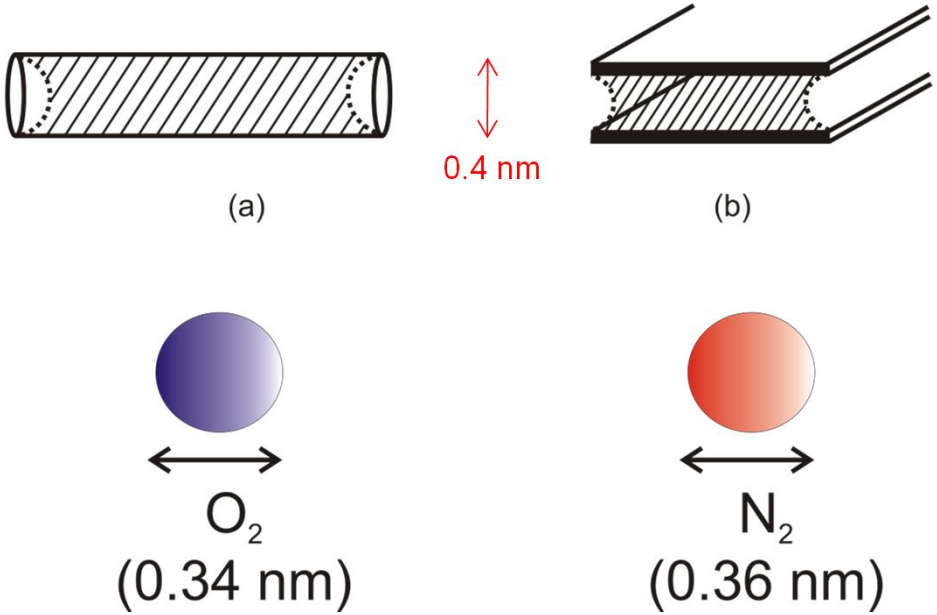
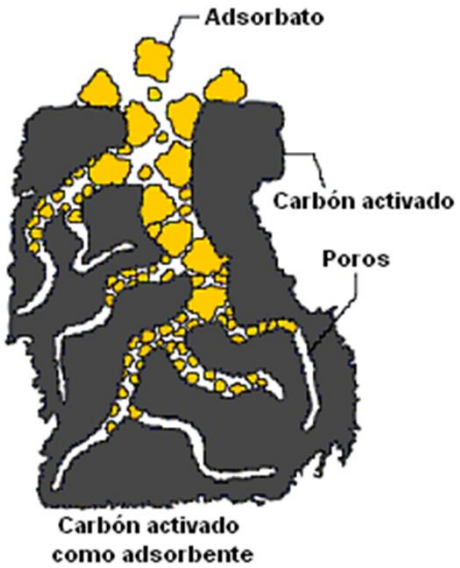
Selectivity by different kinetics





✓ *Introduction*

Why carbon molecular sieves?



Slit-shaped micropores

Porosity can be tailored

Rather "inert" surface

Adsorption of non-polar species favoured,

Surface chemistry can be easily modified,

Many physical forms (granular, pellets, fibres, cloth, felt, monoliths, etc.)

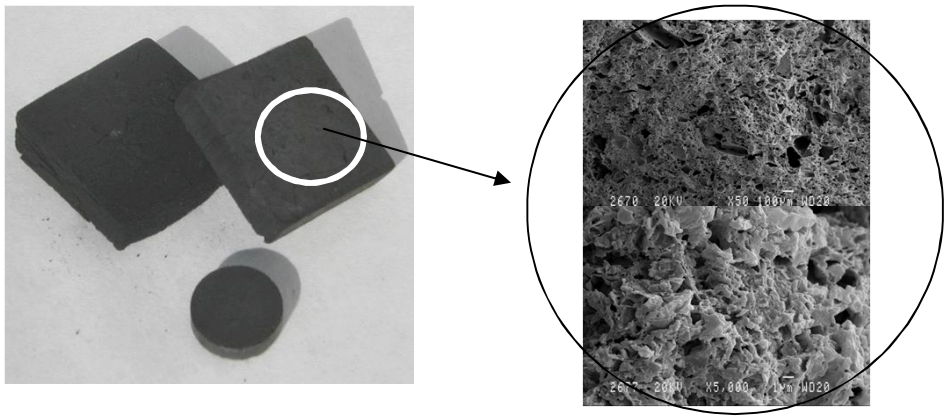
↓

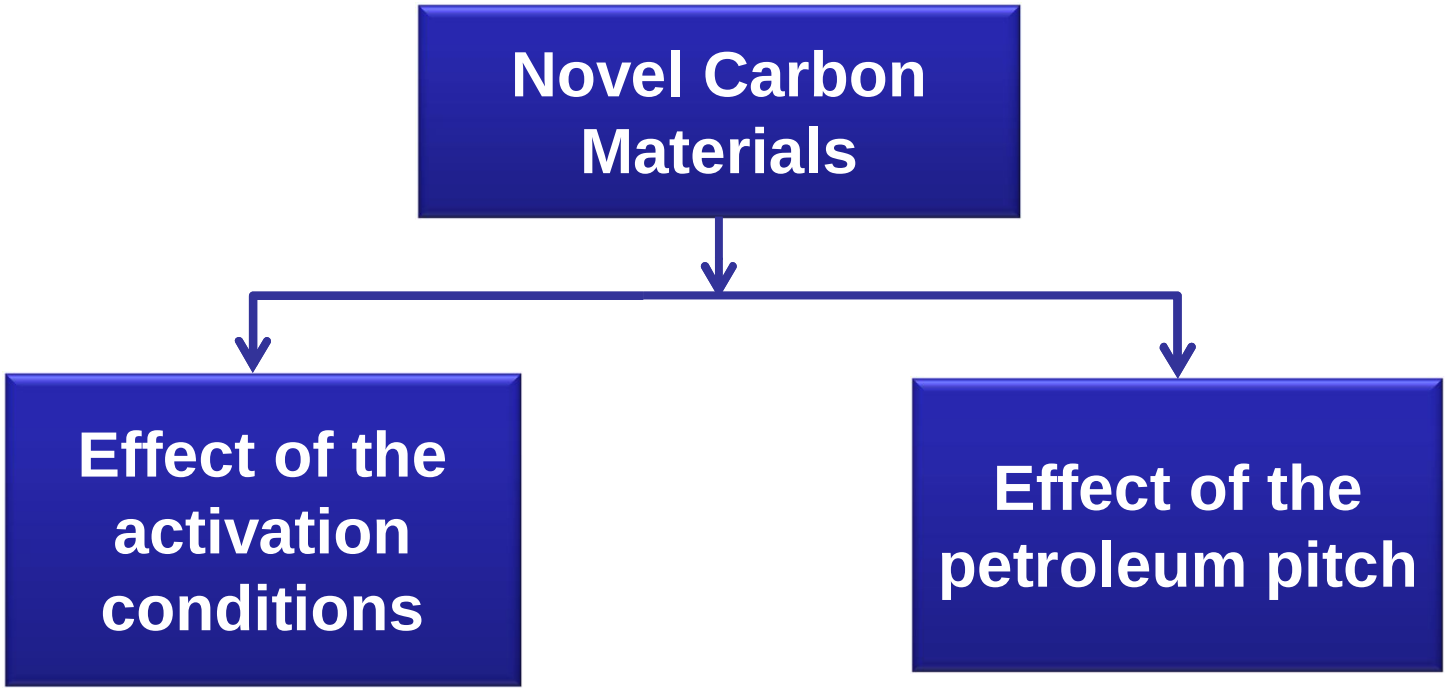
Unparallelled flexibility

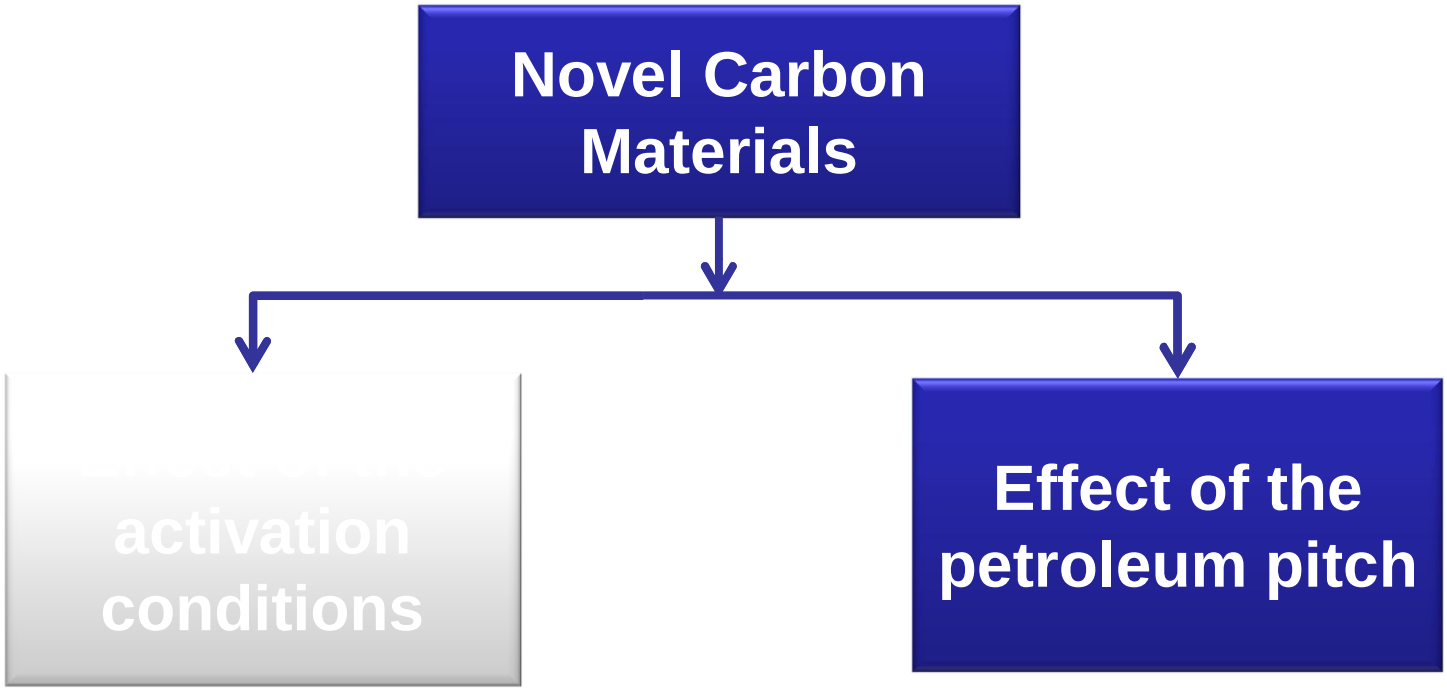
✓*Objective*

Synthesis of very high porosity CMS from petroleum residues for selective CO_2 adsorption vs. other molecules of similar molecular dimensions (N_2 and CH_4)

Synthesis of monolithic CMS without the use of a binder:



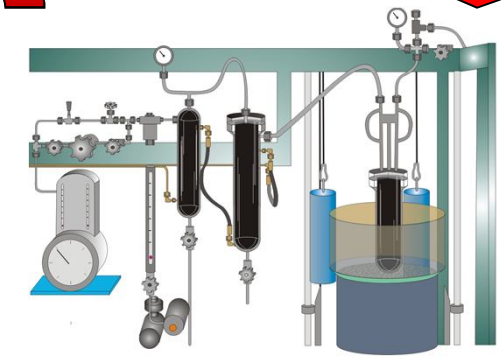

Novel Carbon Materials
Effect of the activation conditions
Effect of the petroleum pitch


Novel Carbon Materials
activation conditions
Effect of the petroleum pitch

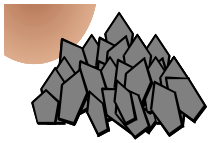
✓*Experimental Section*

440ºC, 1 MPa,
2-4 Hours.

Ball Milling



VR (vacuum residue)
DO (decanted oil)



Mesophase pitch
Ø≤500µm

MP-2 (2 h) { VR-5; DO-10
MP-4 (4 h) { VR-93; DO-88

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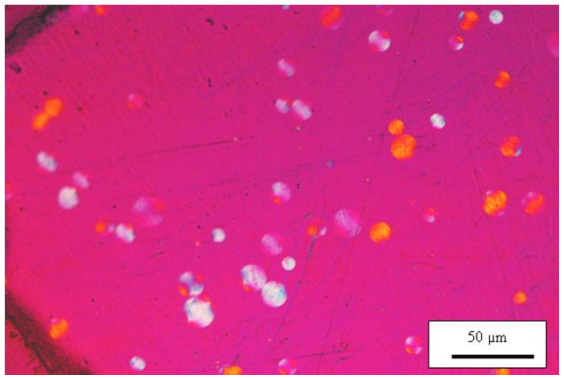
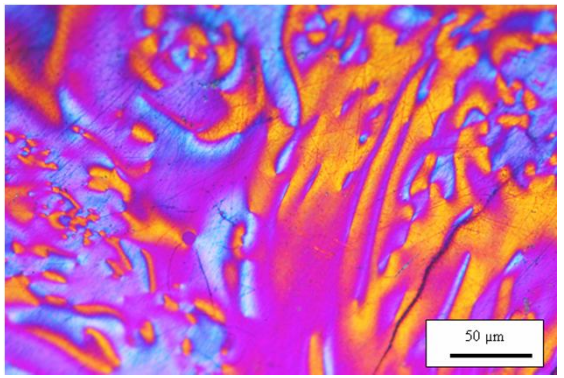
✓Experimental Section

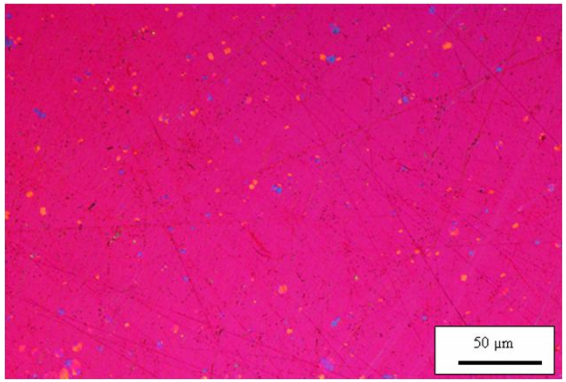
DO-10

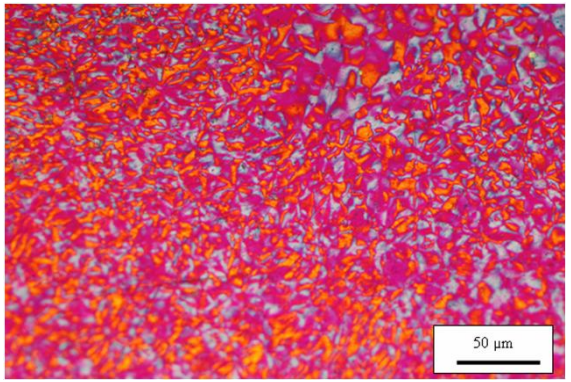




DO-88

VR-5





VR-93

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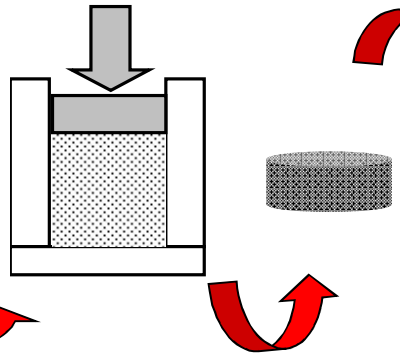
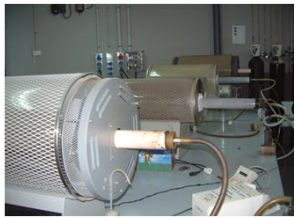
✓Experimental Section

+ KOH

30 min, 300 rpm

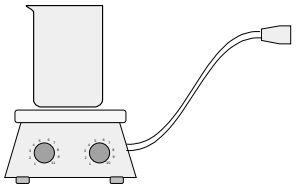


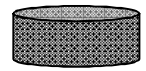
Conforming Press
400 MPa



Activation
800ºC, 2 Hours

Washing





ACM

MP + KOH (1:3)
(VR-5, VR-93, DO-10, DO-88)

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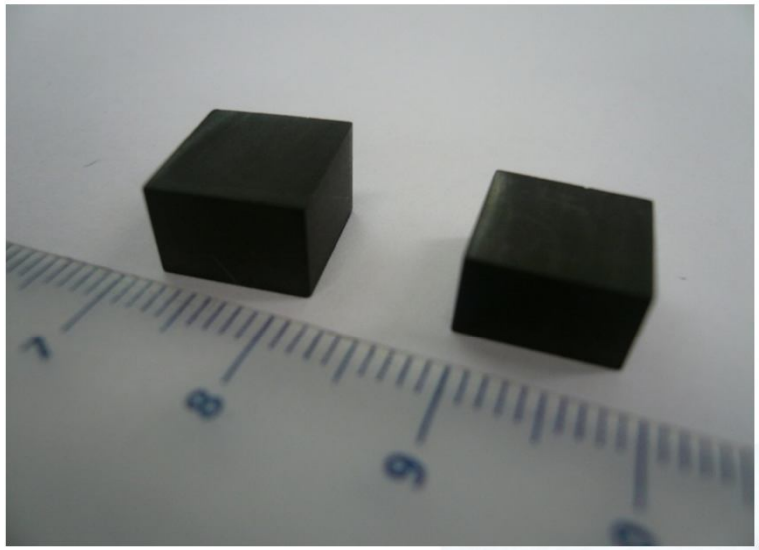
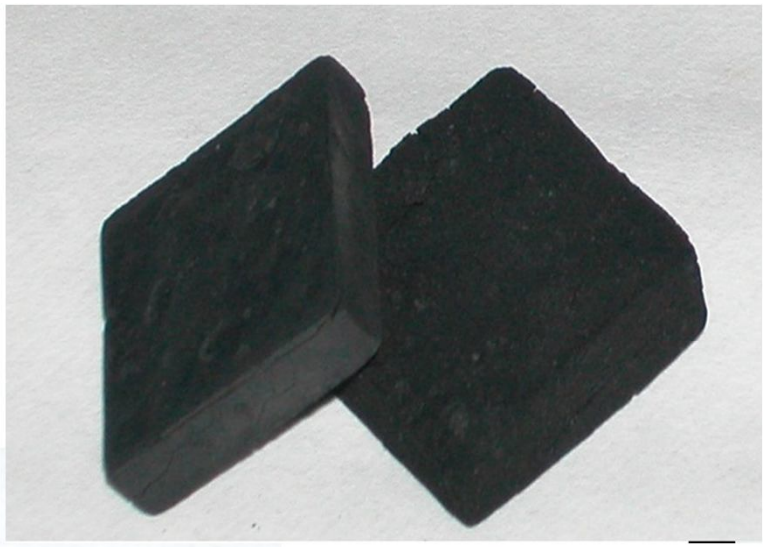
✓Results and discussion





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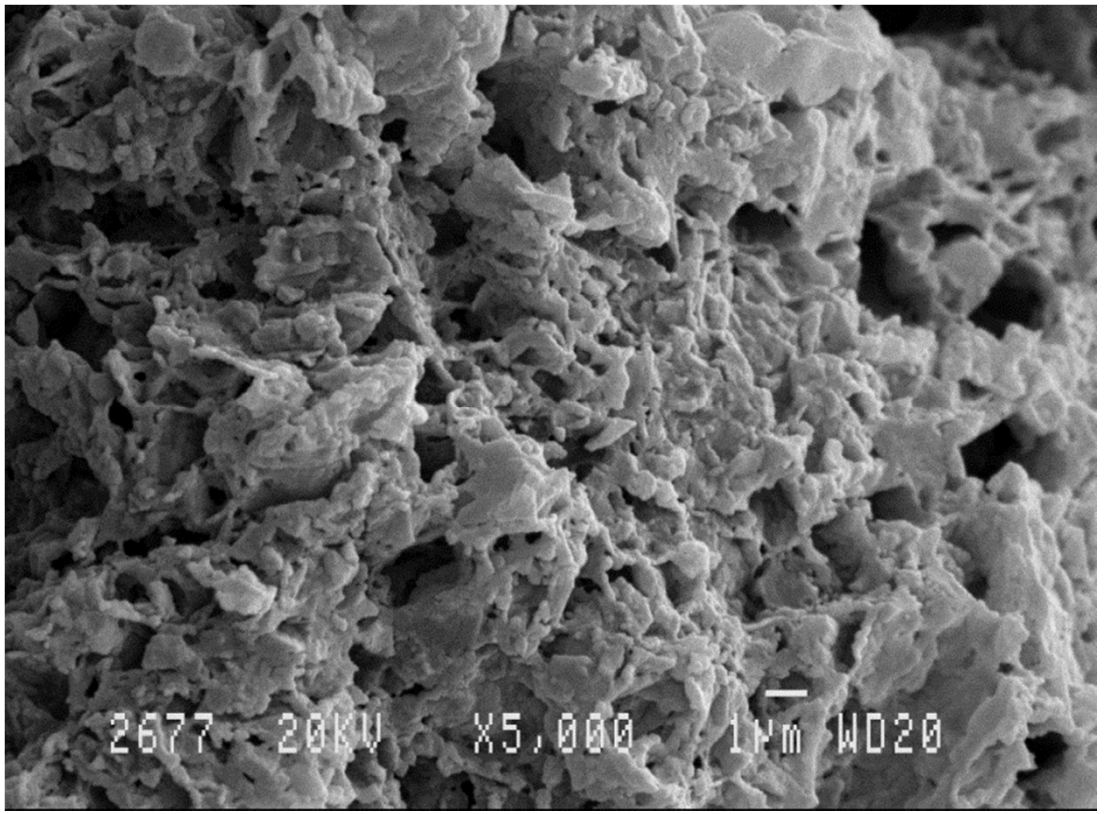
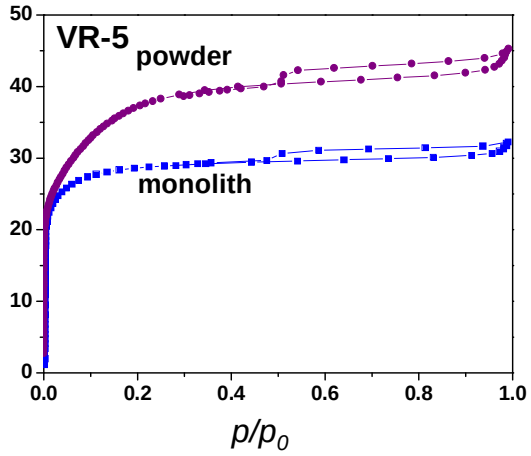
✓Results and discussion

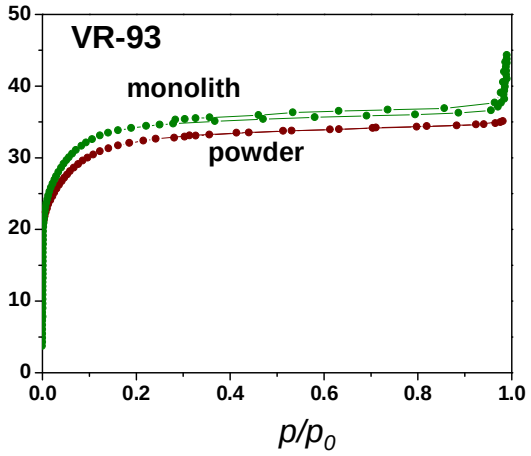
Scanning Electron Microscopy

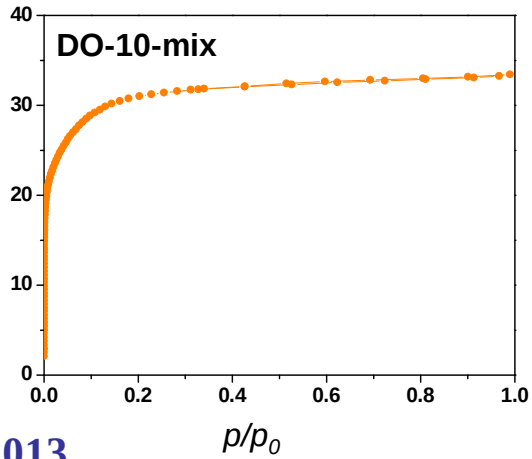


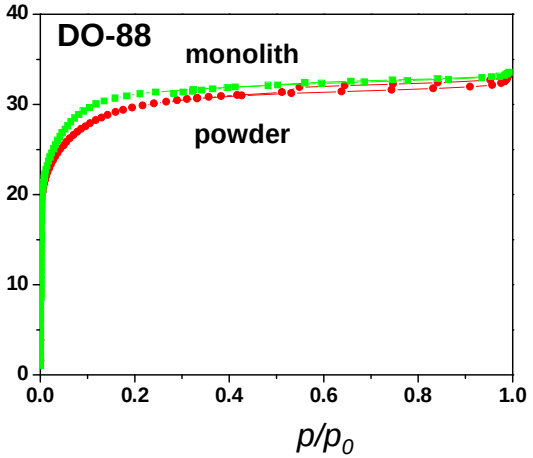
✓ Results and discussion

N_2 adsorption/desorption isotherms at 77 K









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✓Results and discussion

Textural characteristics N_2 and CO_2 data

Muestra	S_{BET} (m^2/g)	V_0 (cm^3/g)	V_t (cm^3/g)	V_n (cm^3/g)
VR-5-P	3100	1.45/1.02	1.57	0.85
VR-5-M	2450	1.03	1.12	0.95
VR-93-P	2895	1.28/1.06	1.42	0.80
VR-93-M	2720	1.21	1.22	1.08
DO-10-mix	2600	1.16/0.93	1.16	0.75
DO-88-P	2440	1.09/0.88	1.14	0.69
DO-88-M	2660	1.16/1.00	1.16	0.74

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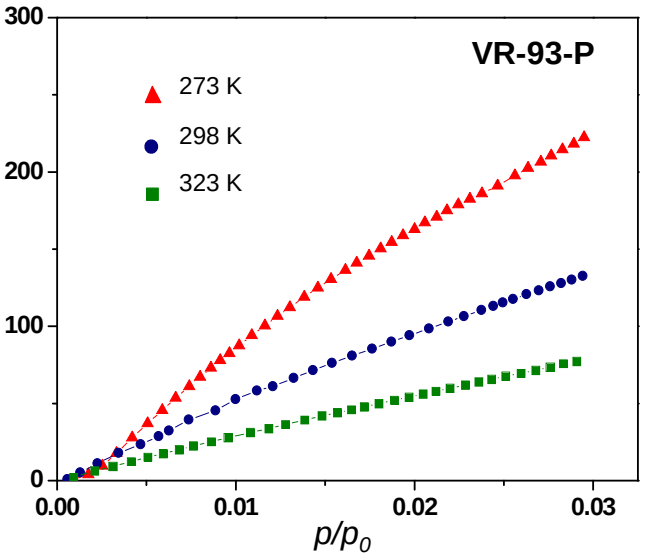
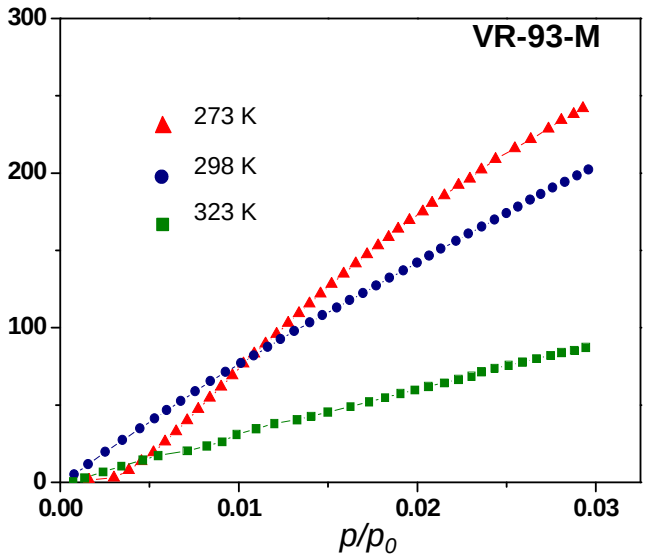
✓ Results and discussion

CO_2 adsorption isotherms at different temperatures (VR-93)





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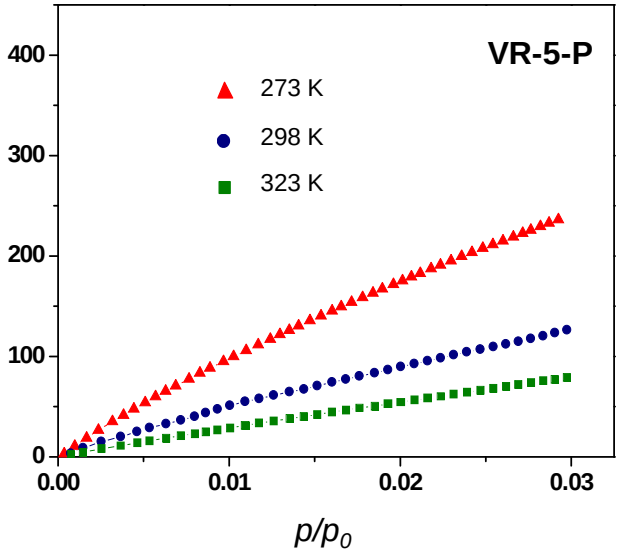
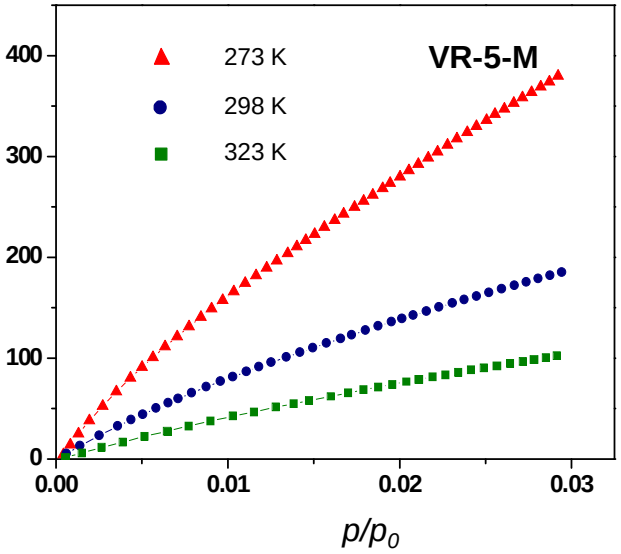
✓ Results and discussion

CO_2 adsorption isotherms at different temperatures (VR-5)





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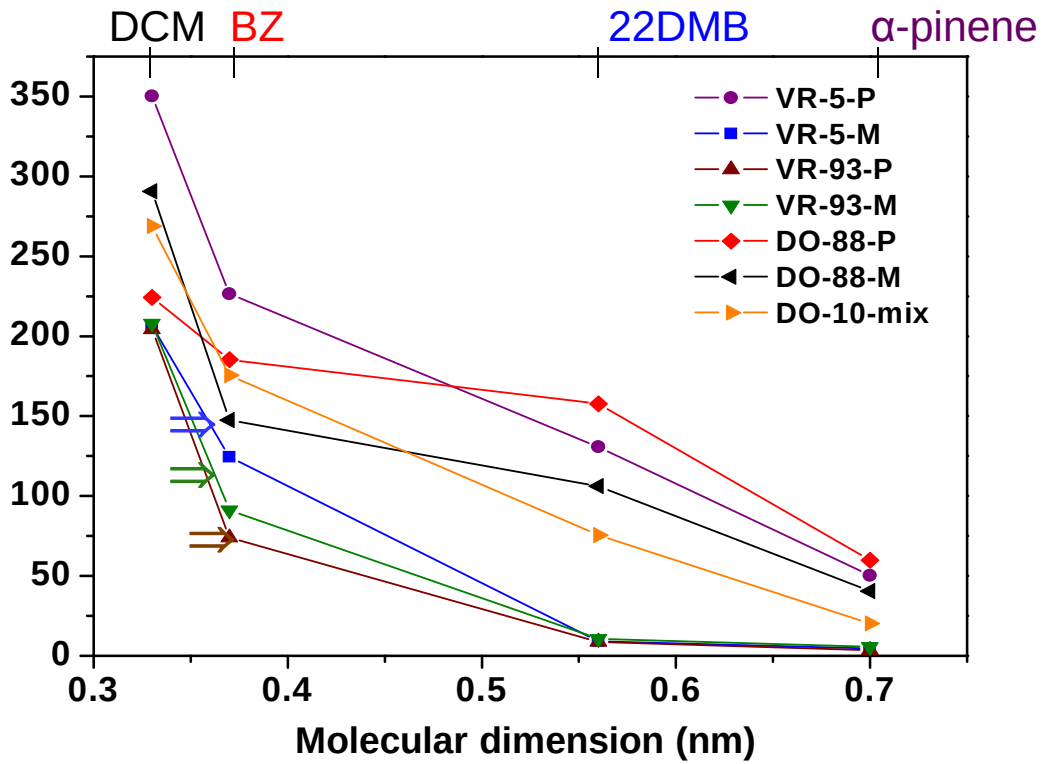
✓Results and discussion

Immersion calorimetry into different liquids



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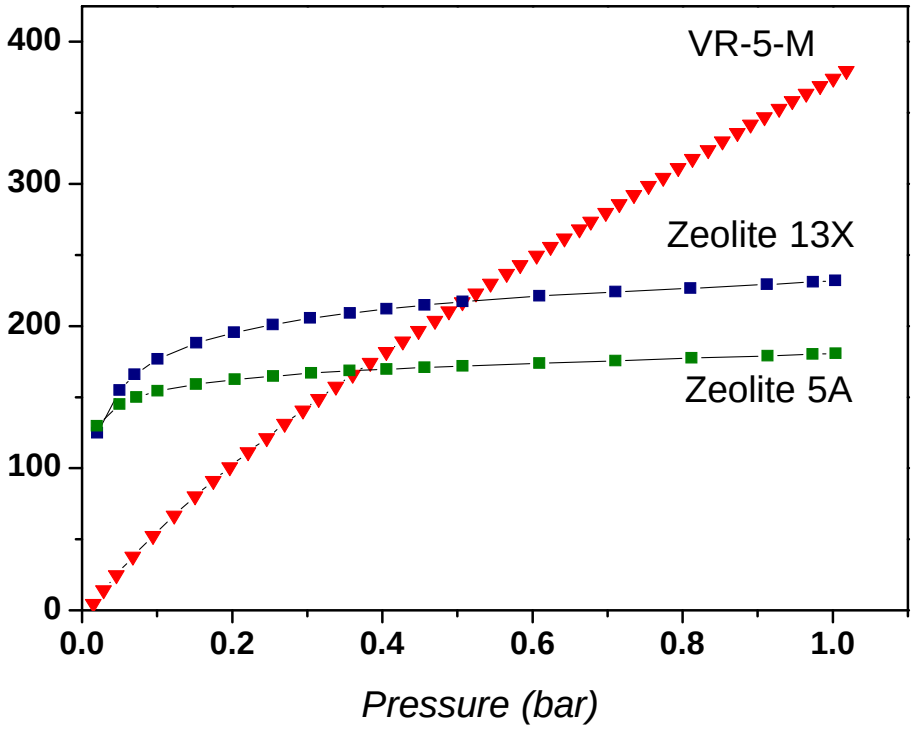
✓Results and discussion

Carbon Molecular Sieves vs. Zeolites



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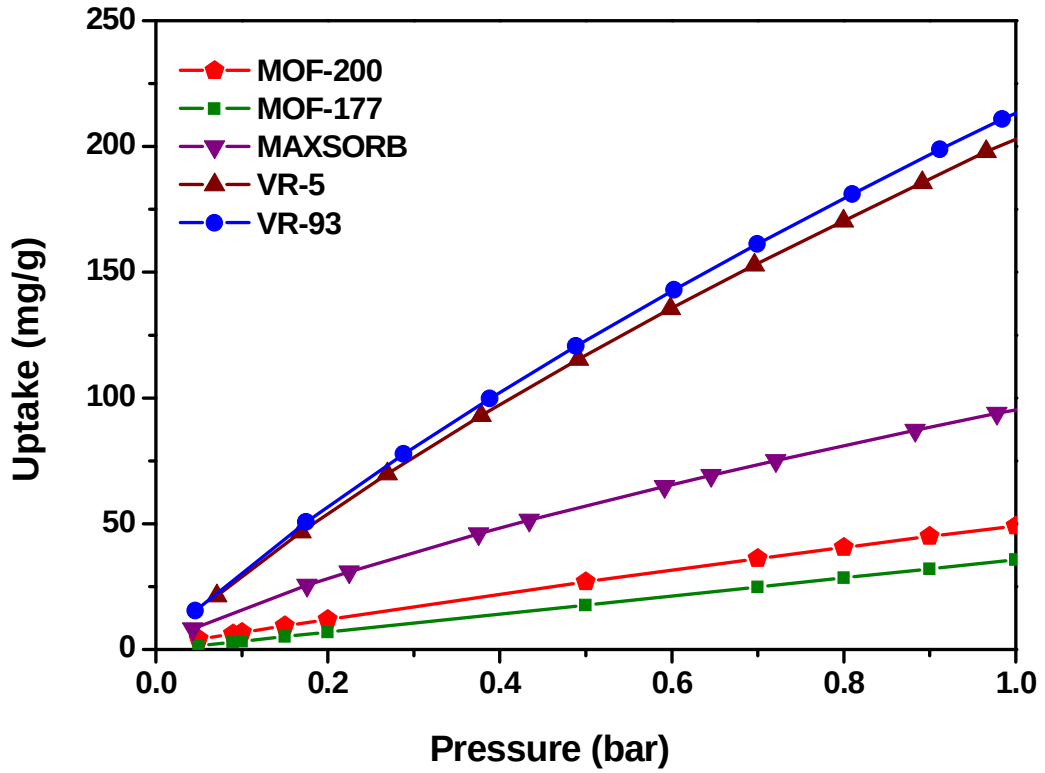
✓Results and discussion

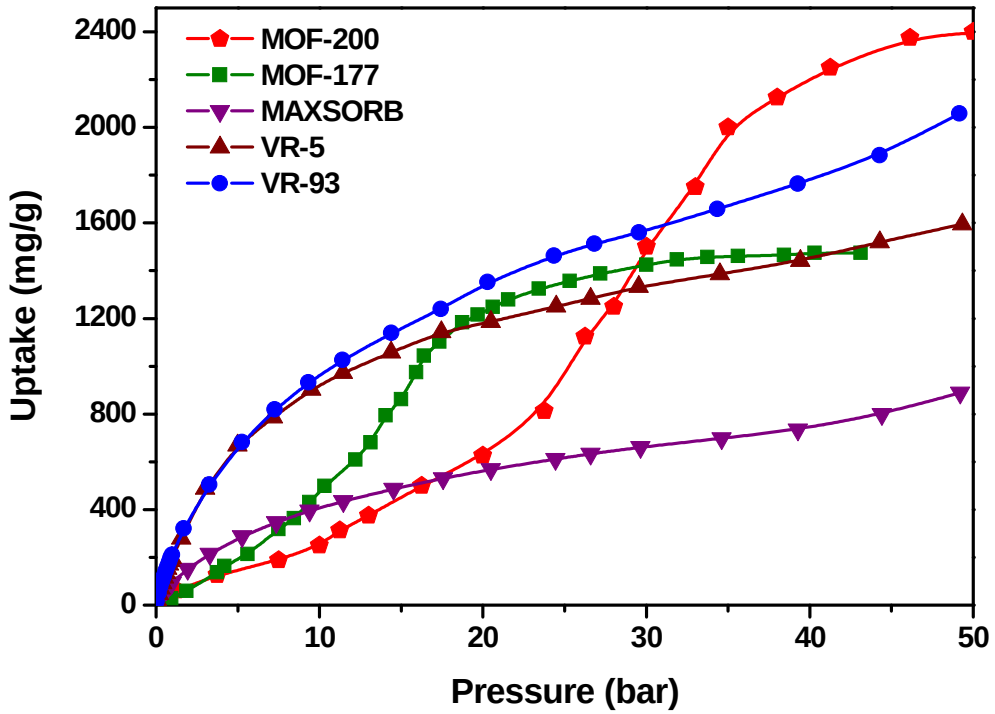
Carbon molecular sieves vs. MOFs materials



J. Silvestre-Albero et al. ChemComm 47, 6840-6842 (2011)

✓Results and discussion

Carbon molecular sieves vs. MOFs materials



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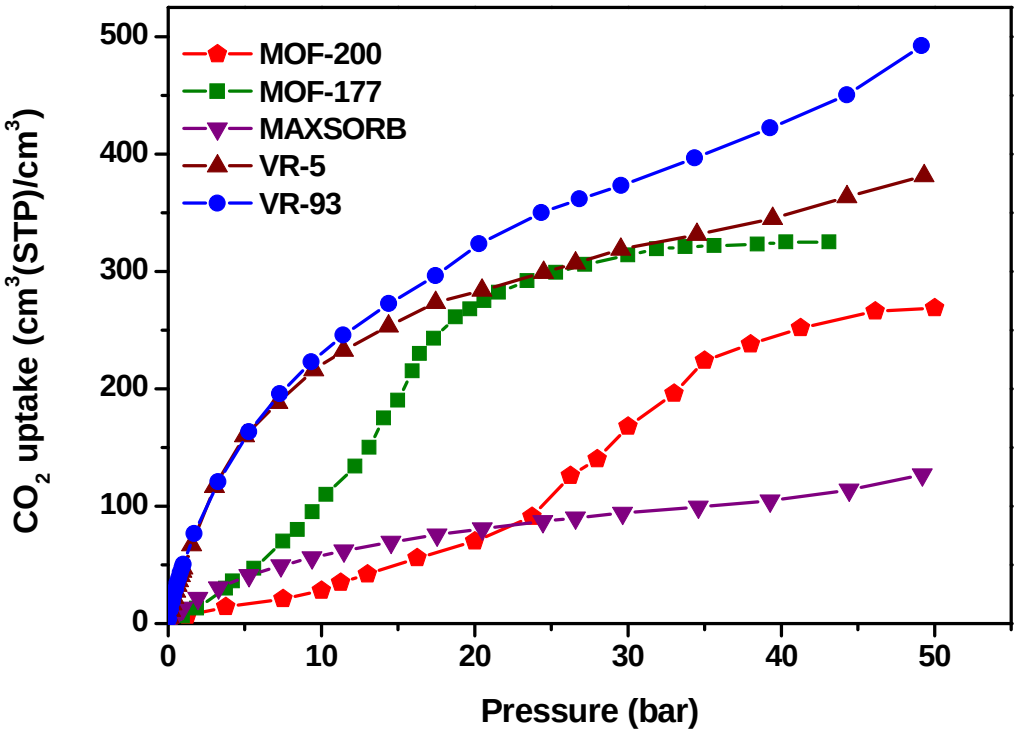
✓Results and discussion

Carbon molecular sieves vs. MOFs materials



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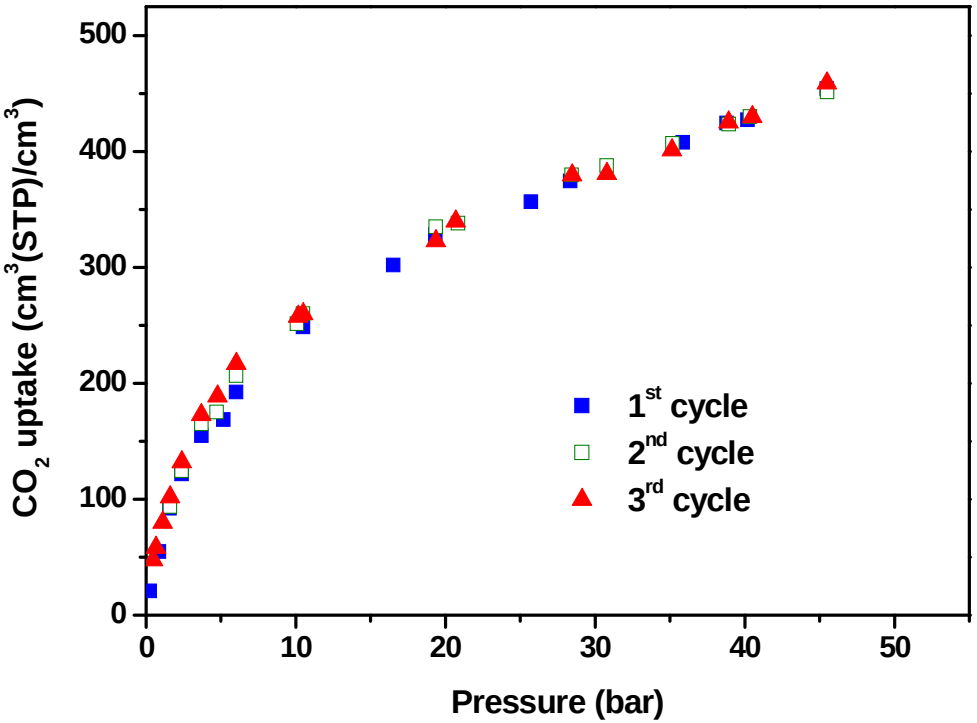
✓Results and discussion

Regeneration of the carbon molecular sieves



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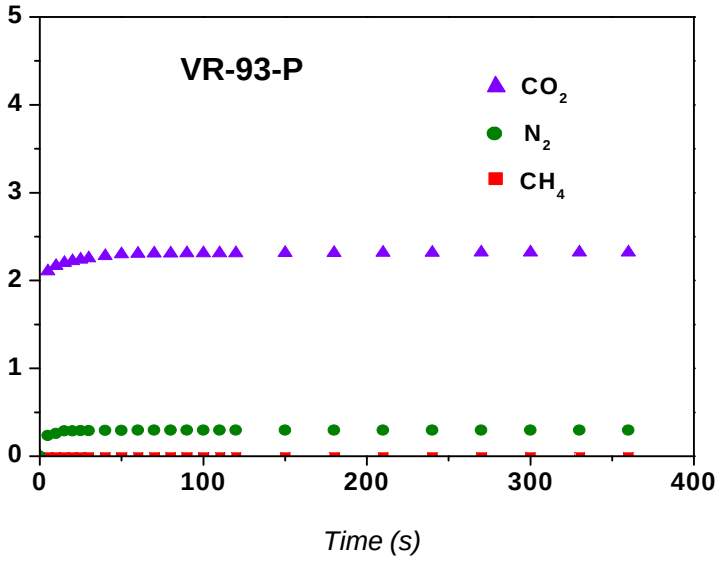
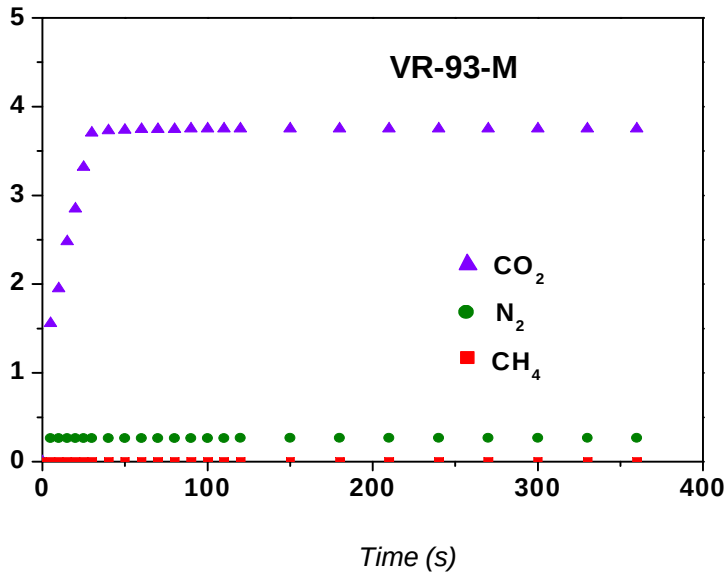
✓Results and discussion

Kinetics of adsorption of CO_2, N_2 and CH_4 at 298 K (VR-93)

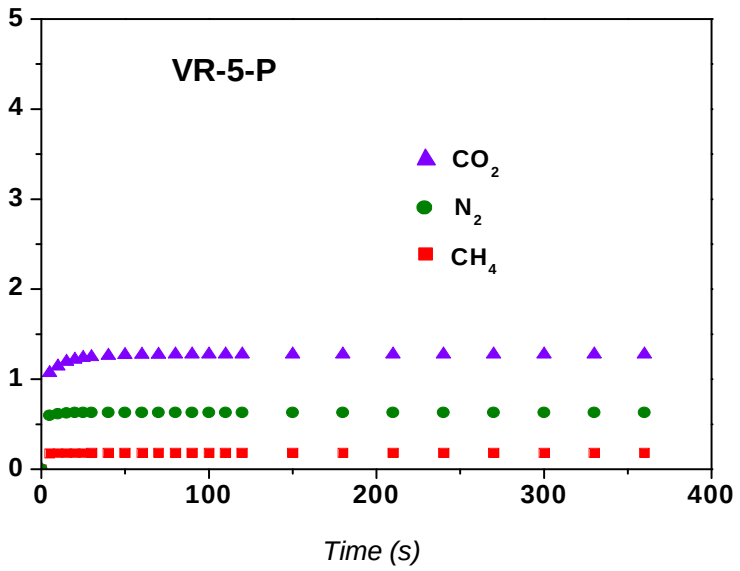


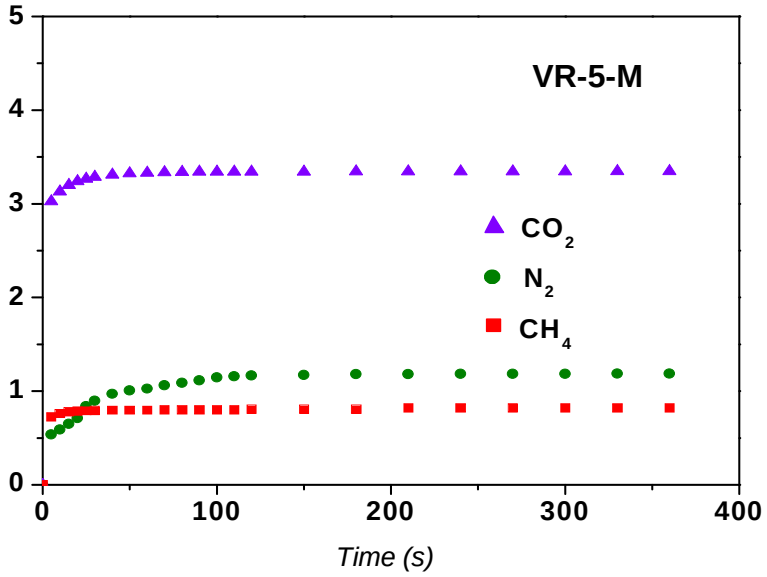


A. Wahby et al. ChemSusChem 3, 974-981 (2010)

✓Results and discussion

Kinetics of adsorption of CO_2, N_2 and CH_4 at 298 K (VR-5)





A. Wahby et al. ChemSusChem 3, 974-981 (2010)

✓*Summary*

✓**High surface area (up to 3000 m^2/g) carbon molecular sieves can be prepared from petroleum pitch using KOH as activating agent.**

✓**These carbon molecular sieves exhibit an extremely high CO_2 adsorption capacity (up to 380 mg/g).**

✓**The size of the pore entrance on these CMSs highly depends on the petroleum residue, the pyrolysis conditions used and the activation degree. For samples VR it is below 0.56 nm.**

✓**Either at low (1 bar) and high (50 bar) pressure, CMSs are able to overcome the incomparable adsorption behavior described for MOFs materials.**

✓**CMSs are able to discriminate CO_2 for molecules of similar dimensions (e.g. CH_4 and N_2).**

✓ *Acknowledgement*

Laboratorio de Materiales Avanzados

National Projects:
NAN2004-09267-C03-03
MAT2007-61734

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN

EU Projects: FRESP (Advanced First Response Respiratory Protection)

SEVENTH FRAMEWORK PROGRAMME


10th International Symposium on the Characterization of Porous Solids (COPS-X)
Granada (Spain)
11-14 May 2014

Location

Granada is located in the South of Spain in the "Andalucia Region"

How to arrive:

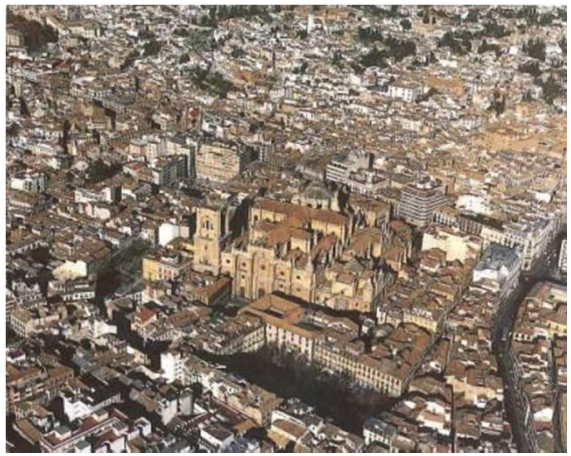
-Granada is located 434 Km south from Madrid. There are several daily trains from Madrid to Granada (4h 25 min; shorter time in 2014)

-Granada´s airport is 17 Km from the city. There are direct national flights to Madrid (Iberia), Barcelona (Vueling) and Palma de Mallorca (Iberia, Air Europa). There are also International connections with Paris (Vueling), Milano (Ryanair) and Bologna (Ryanair)

-International airport of Malaga is located 125 Km from Granada.

The City of Granada

The “Alhambra” Palace



The Catedral

Generalife Palace

Albaicín

Granada Congress Centre

The “Tapas”

Around Granada

Sierra Nevada

The Alpujarras

Organization

Local Scientific Committee:

-Dr. Francisco Carrasco-Marín, University of Granada
-Dr. Agustín F. Pérez Cadenas, University of Granada

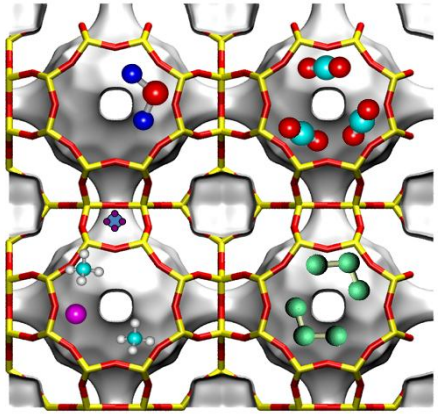
International Scientific Committee:

-Dr. Tina Düren, University of Edinburgh, UK
-Dr. Stefan Kaskel, TU Dresden, Germany
-Dr. Philip Llewellyn, University of Provence, France
-Dr. Joaquín Silvestre-Albero, University of Alicante, Spain

Honorary Scientific Committee:

-Prof. Dr. Francisco Rodríguez-Reinoso, Spain
-Prof. Dr. Jean Rouquerol, France
-Prof. Dr. Kenneth Sing, UK
-Prof. Dr. Klaus K. Unger, Germany

Materiales en Adsorción y Catálisis



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