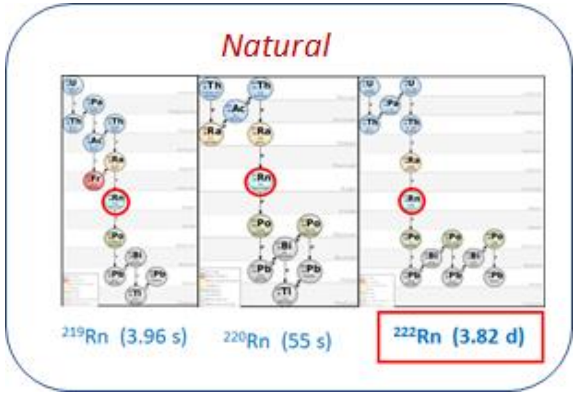
Study and development of new radon adsorbents Update of the IRENE Project

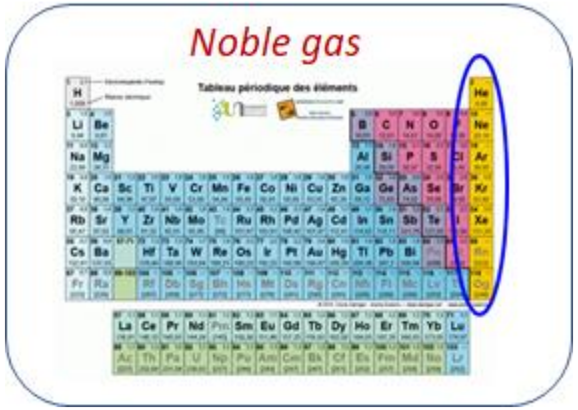
(**I**nnovative mate**R**ials for **E**xtreme rado**N** captur**E**)

LRT 2026, York

Hichem Tedjditi

23/09/2026



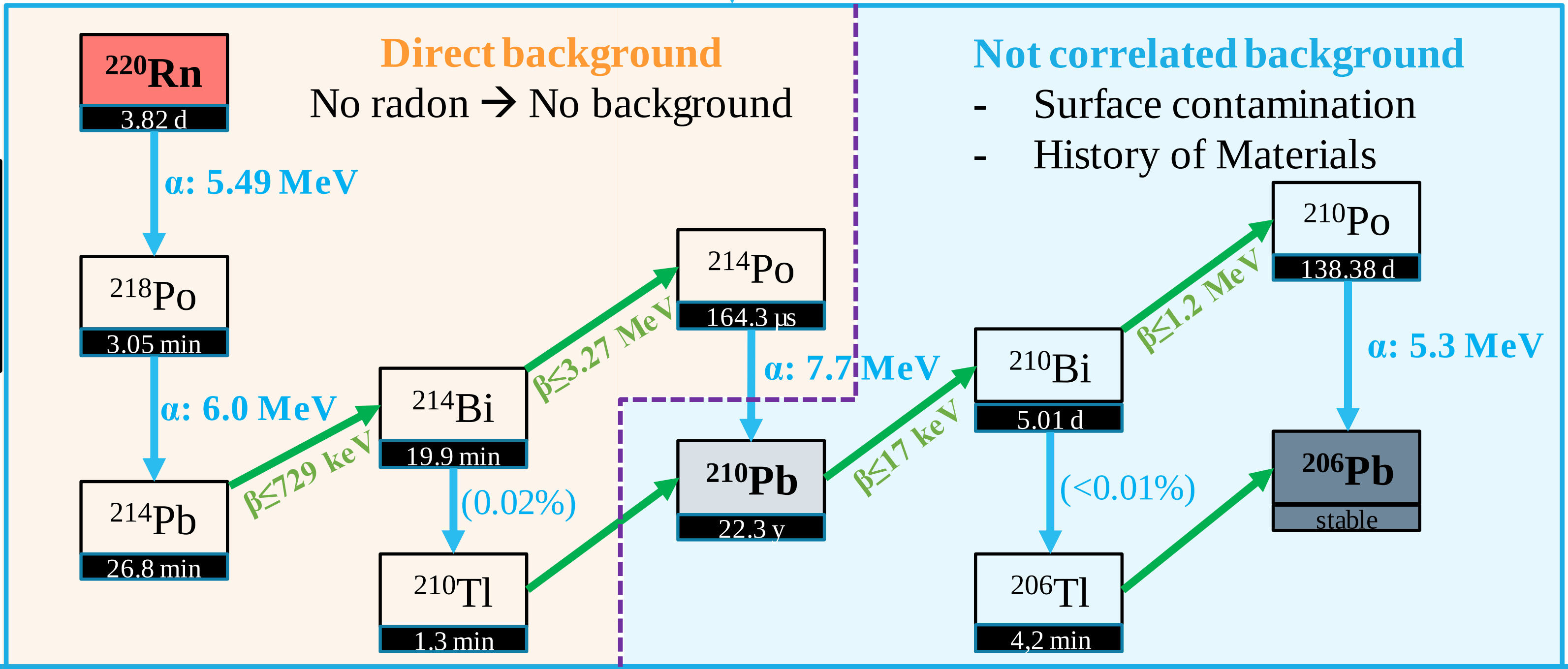


Natural, Radioactive, Noble gas from the U and Th chains

Emanation

- Easy to transport, complicated to capture
- Short half-life, high intrinsic activity

Adsorption



→ α from 5 to 8 MeV
→ β ≤ 3.27 MeV
→ γ ≤ 3.18 MeV

Radon Capture

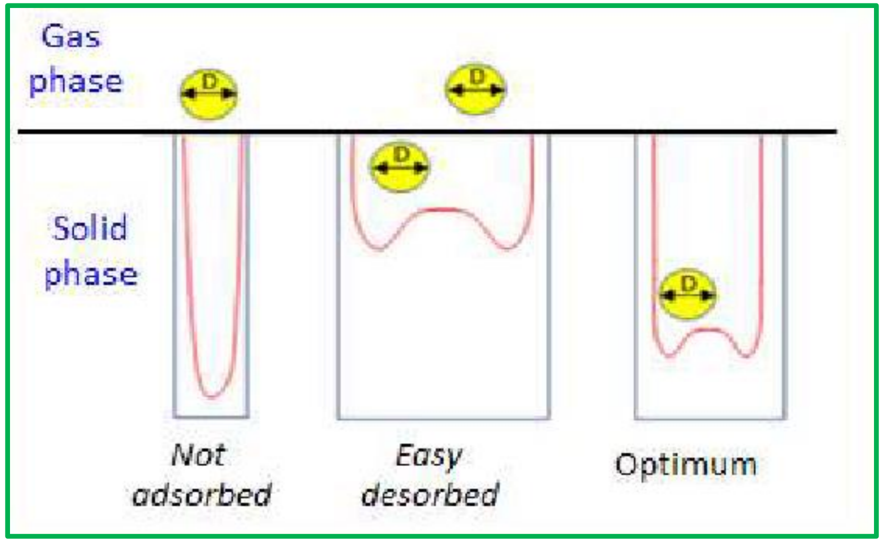
Rn is a Noble gas:

- No chemistry → Physical process

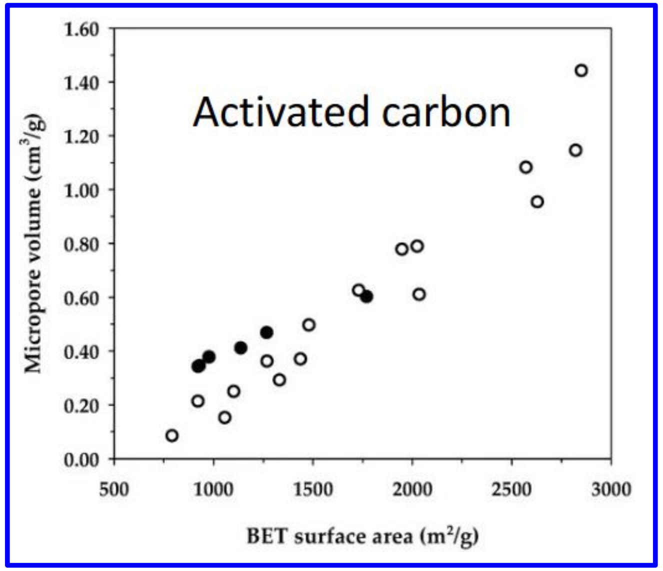
Physical adsorption:

→**Surface** capture by Van der Waals forces

→Use of porous materials: very high surface materials, up to 4000m²/g



Need to optimized Porosity



IRENE history

→ 2015 : Study of Rn capture in 50 commercial or research microporous materials (SuperNEMO)

AC CMS Aerogel

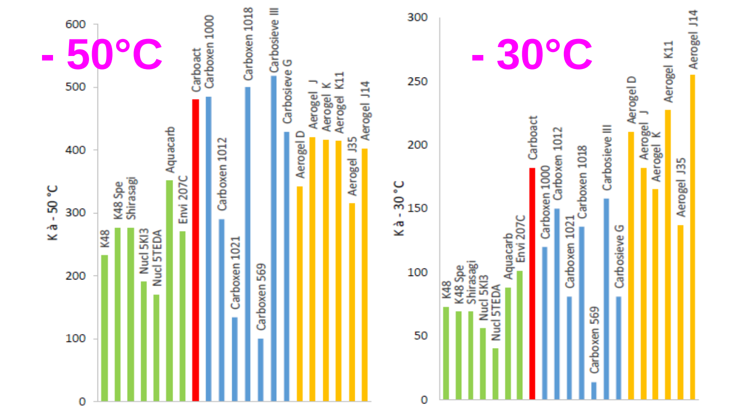


Figure 82 : Coefficient d'adsorption K en fonction du type d'adsorbant à - 50 °C et - 30 °C. En vert charbon actif, en bleu CMS, en jaune aérogel, en rouge Carboact.

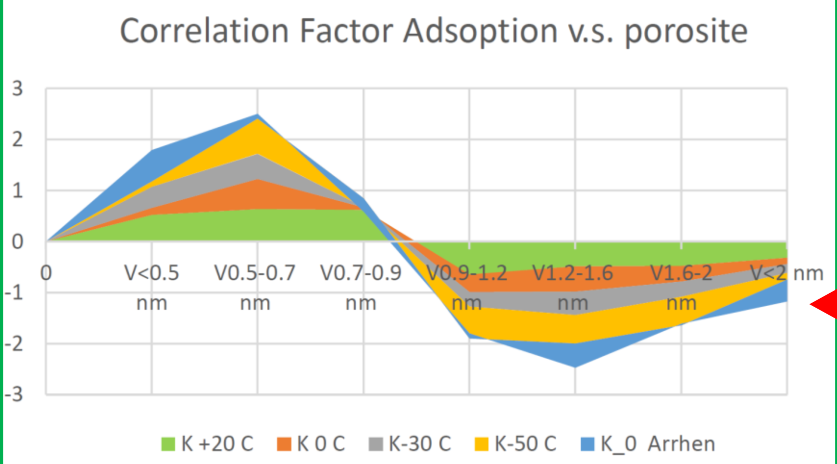
Adsorption @ – 50°C and -30°C in AC, CMS, Aerogels

Micro porosity from 0.5 to 2 nm

Échantillons	S_{BET} N_2 (m^2/g)	$V_{<0,5\,nm}$ (cm^3/g)	$V_{0,5\text{-}0,7\,nm}$ (cm^3/g)	$V_{0,7\text{-}0,9\,nm}$ (cm^3/g)	$V_{0,9\text{-}1,2\,nm}$ (cm^3/g)	$V_{1,2\text{-}1,6\,nm}$ (cm^3/g)	$V_{1,6\text{-}2\,nm}$ (cm^3/g)	$V_{<0,7\,nm}$ (cm^3/g)	$V_{0,7\text{-}2\,nm}$ (cm^3/g)	$V_{<2\,nm}$ (cm^3/g)
Carbosieve SIII (1)	1062	0,076	0,233	0,062	0,018	0,020	0,000	0,308	0,102	0,410
Carboxen 1000 (2)	812	0,064	0,161	0,044	0,001	0,000	0,000	0,225	0,045	0,270
Carboxen 569 (3)	299	0,074	0,011	0,000	0,000	0,000	0,000	0,085	0,000	0,085
K48S (4)	799	0,074	0,138	0,034	0,033	0,032	0,006	0,212	0,105	0,317
Nucleacarb 208C 5TEDA (5)	1298	0,053	0,136	0,084	0,087	0,106	0,044	0,189	0,321	0,510
SHIRASAGI G2x4 (6)	1383	0,051	0,161	0,096	0,090	0,103	0,033	0,212	0,322	0,534
Carboact (7)	1096	0,077	0,206	0,053	0,033	0,048	0,022	0,283	0,156	0,439
Environcarb 207C (8)	1073	0,075	0,181	0,058	0,046	0,050	0,011	0,256	0,165	0,421
K48 (9)	793	0,078	0,137	0,026	0,034	0,034	0,005	0,215	0,099	0,314
Nuclearcarb 208 5KI3 (10)	1315	0,057	0,145	0,081	0,084	0,110	0,046	0,202	0,321	0,522
Carboxen 1012 (11)	1140	0,074	0,145	0,054	0,076	0,078	0,016	0,219	0,223	0,443
Carboxen 1021 (12)	585	0,083	0,049	0,020	0,037	0,026	0,017	0,132	0,100	0,231
Carboxen 1016 (13)	77	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Carboxen 1018 (14)	804	0,061	0,155	0,045	0,010	0,024	0,014	0,216	0,092	0,308
Aquacarb 207C (15)	1040	0,063	0,165	0,066	0,044	0,052	0,019	0,228	0,181	0,409
Carbosieve G (16)	1273	0,074	0,183	0,112	0,046	0,050	0,025	0,257	0,233	0,490

Chemical composition

Échantillons	% N	% C	% H	% S
Carbosieve SIII (1)	0,5	97,3	0,1	0,0
Carboxen 1000 (2)	0,3	92,6	0,5	5,1
Carboxen 569 (3)	0,4	94,3	0,1	3,8
K48 S (4)	0,3	89,8	1,3	0,0
Nucleacarb 208C 5TEDA (5)	1,7	91,6	1,3	0,0
SHIRASAGI G2x4 (6)	0,5	94,9	0,8	0,0
Carboact (7)	0,3	92,5	1,0	0,0
Environcarb 207C (8)	0,3	91,6	0,9	0,0
K48 (9)	0,3	90,4	1,2	0,0
Nuclearcarb 208 5KI3 (10)	0,3	86,7	0,8	0,0
Carboxen 1012 (11)	0,1	97,3	0,6	0,0
Carboxen 1021 (12)	0,4	95,8	0,2	2,1
Carboxen 1016 (13)	0,1	99,7	0,1	0
Carboxen 1018 (14)	0,1	94,9	0,7	2,2
Aquacarb 207C (15)	0,2	90,8	1,7	0,0
Carbosieve G (16)	0,0	87,1	1,3	0,0



Optimal porosity:

- 0.5 – 0.7 nm (Rn 0.4 nm)

Small effect on the chemical composition (Sulphur)

IRENE history

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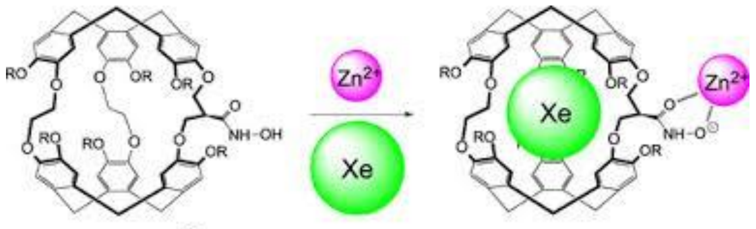

2; R = $CH_2COO^{\ominus}$

- Used for the complexing of Xe
- Adjustable size

Institut des Sciences Moléculaires de Marseille
UMR 7313

Atomic Radius

Gas	Van der Waals (nm)	Covalent
Xe	0.216	0.130
Rn	0.220	0.145

Compétition Xe / Rn

Rn Adsorption (CPPM)

Adsorbant	K (m^3/kg) @-30°C
YC-125: Cryptophane A/MCM-41	103,2 ± 25
AC K48 special	66,6 ± 5

Xe Adsorption (MADIREL)

Echantillon	Adsorption Xe (mmol/g)
Cryptophane A (MCM-41)	0.176 ±0.010
Cryptophane A (SBA-15)	0.123 ±0.006
Charbon actif Silcarbon K48	2.31 ±0.04

13.12

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→ 2020 : Radon adsorption on silver zeolite

Three commercial Ag Zeolite

Zeolite	Supplier	Chemical formula	Silver content (wt%)	Pore size (Å)
Ag-ZSM-5	Riogen	$Ag_{4.8}[(AlO_2)_{4.8}(SiO_2)_{91.2}] \cdot 16H_2O$	7.9	5.2 × 5.7 and 5.3 × 5.6
Ag-13X	Sigma Aldrich	$Ag_{84}Na_2[(AlO_2)_{86}(SiO_2)_{106}] \cdot xH_2O$	35	10 × 10
Ag-ETS-10	Extraordinary Adsorbents Inc.	$Ag_{16}[Si_{40}Ti_8O_{104}]$	30	4.9 × 7.6

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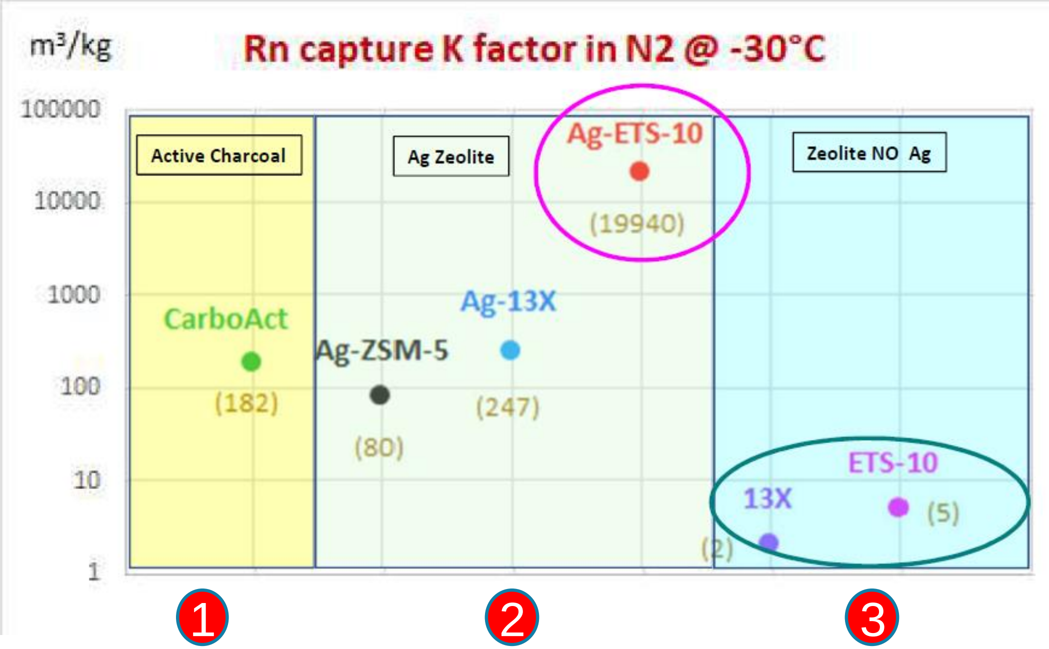
$$K = \frac{Rn\ in\ the\ Adsorbent}{Rn\ in\ the\ Gas}\ [m^3/kg]$$



1 Reference charcoal (carboAct)

2 Commercial Ag zeolites
- Ag-ZSM-5
- Ag-13X
- Ag-ETS-10

3 NO Ag zeolites
- 13X
- ETS-10

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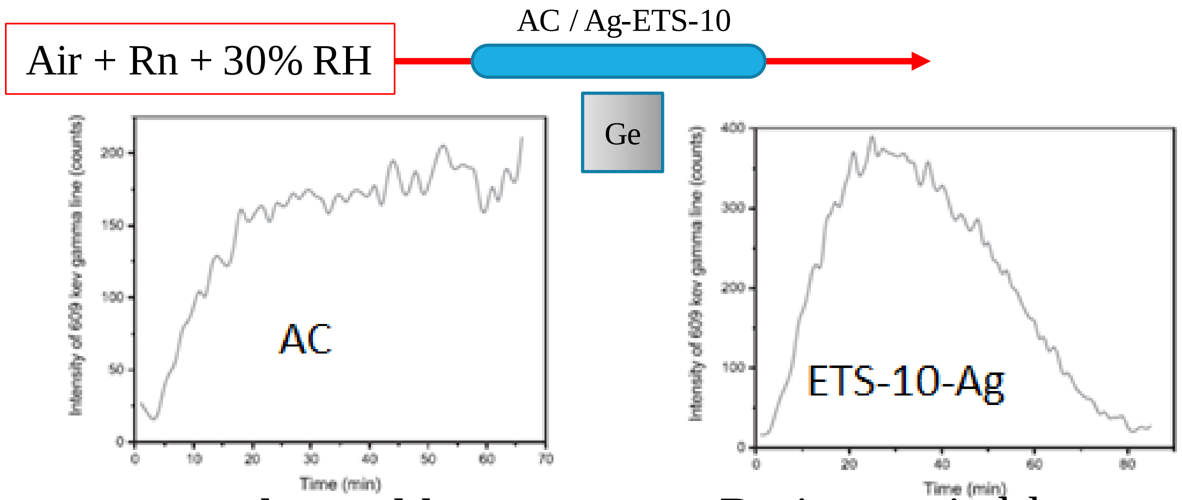
High ^{226}Ra concentration

Echantillon	226Ra (Bq/kg)
K48	< 0,25
NuclCarb 5TEDA	<0,3
ENvCarb 207C	0,28 +- 0,17
Shirasagi	0,164 +- 0,023
CarboAct	0,0023 +- 0,0019
ETS-10-AG	0,988 +- 0,05

High sensitivity to H_2O



Rn reach equilibrium

Rn is emptied by water

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Other results

@ room temperature

Sample	Reference	K factor [m3/kg]
Ag-ETS-10	Heinitz et al.	3400
Ag-ZSM-5	Heinitz et al.	3500
8 Ag-FER-B	Takeuchi et al.	6500

AC @ 20°C : ~ 10 m^3/kg

Very good results but not well understood

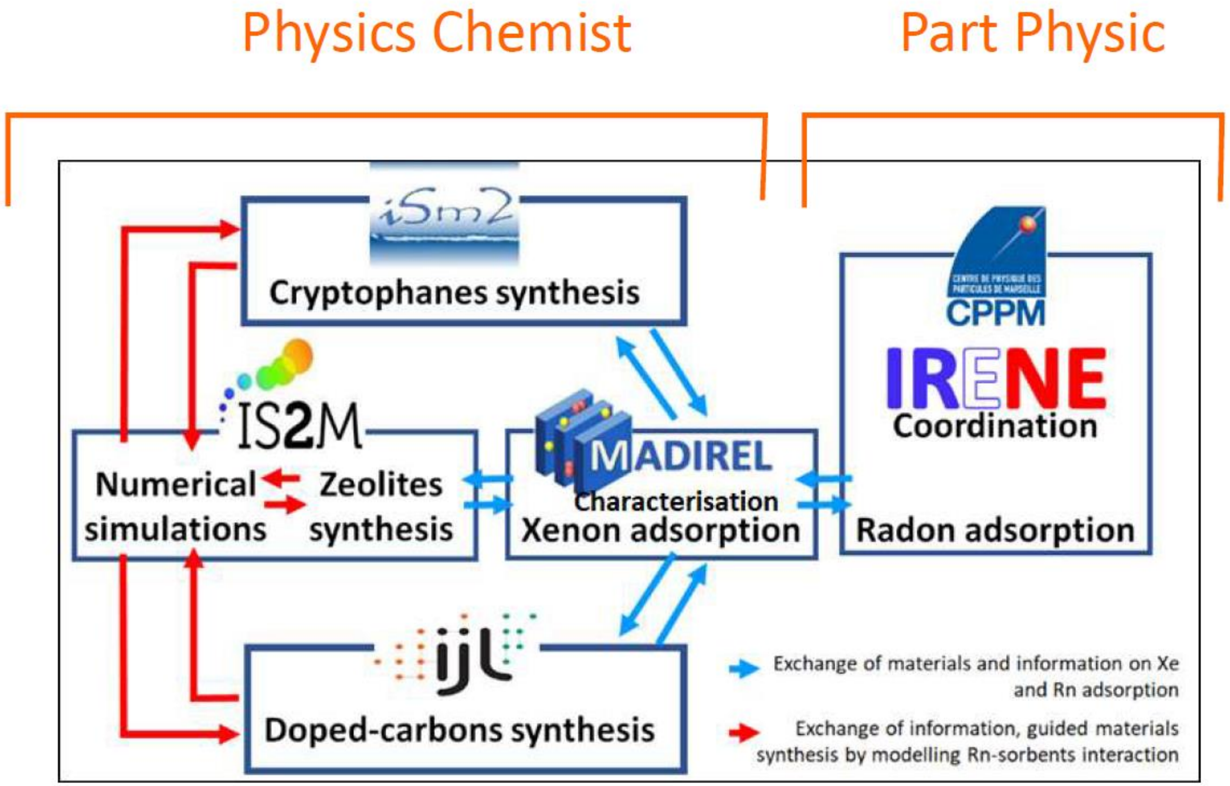
Can we do better ?

- Higher adsorption
- Improved radiopurity
- Lower sensitivity to water

IRENE

Innovative mateRials for Extreme radoN capturE

Understanding and optimizing the capture of Rn in new materials



Project started in February 2024

Philosophy:

- Feedback between the 5 laboratories
- Modelling as a guide
- 3 families of adsorbents:
  - Zeolites
  - Mol. Cages
  - Carbon based
- Xenon as a reference gas
- Radon capture in N_2,He and Xe

IRENE

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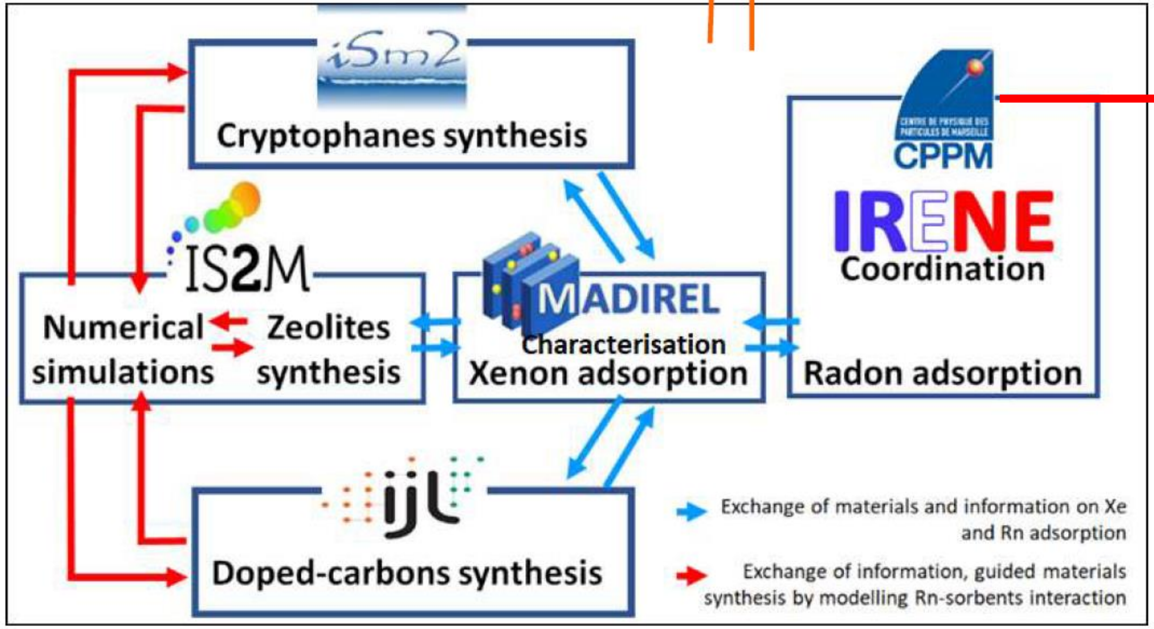
Understanding and optimizing the capture of Rn in new materials

Physics Chemist

Part Physic

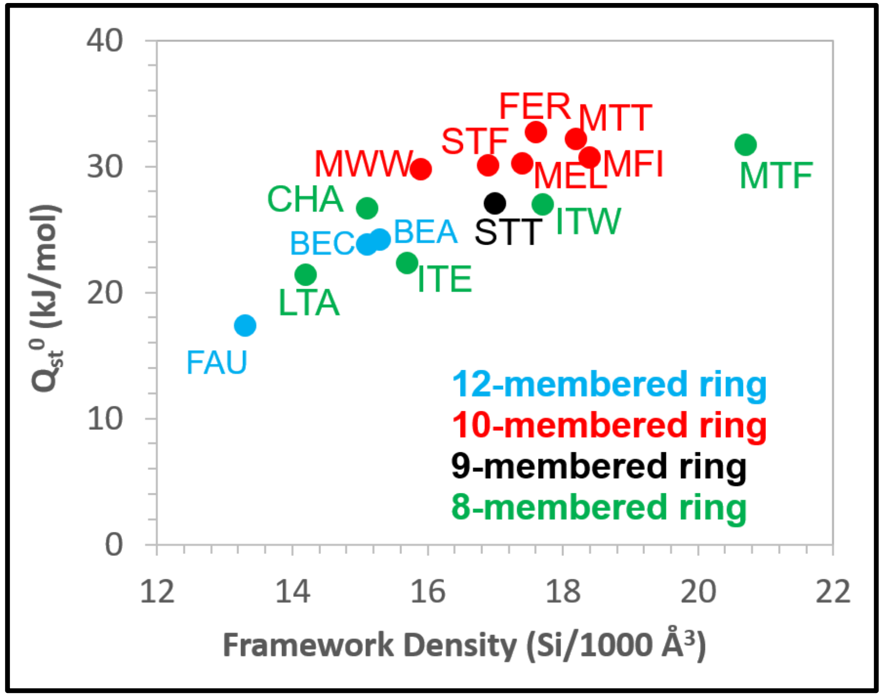


Radon adsorption measurement

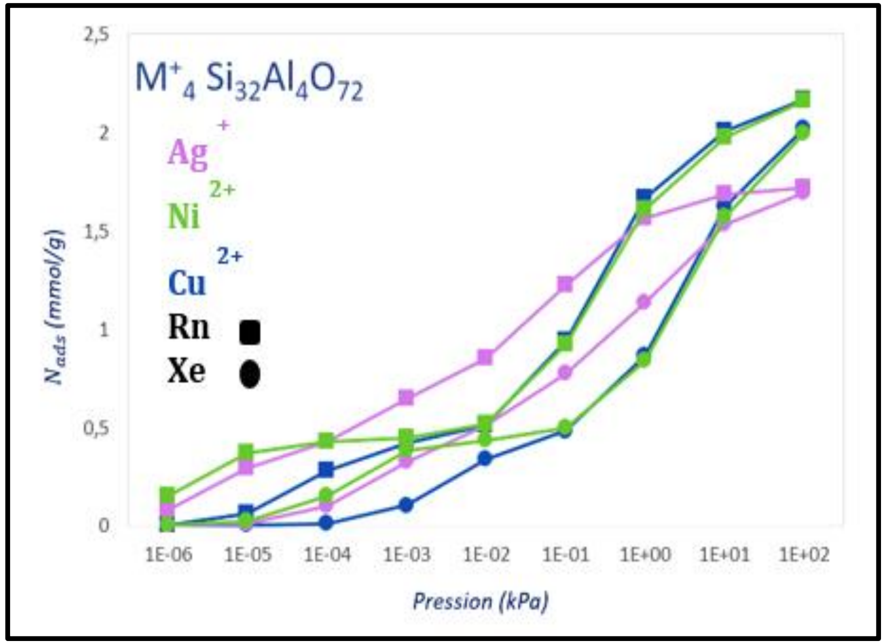
IRENE Results

Simulations

Influence of membered ring configuration



Influence of Metal on Rn/Xe adsorption



→ **Zeolite with 10MR are the best candidate for Rn adsorption**

→ **Cu^{+} Ni^{2+} should perform better than Ag^{+}**

IRENE Results

Synthesis & measurement

Active Charcoal :

- Base Charcoal is Carbio12 G90 with **K = 63,83 ± 5,3 m^3/kg**
- Study of treatments effect that will be applied before metal doping of the AC:
  - NH3
  - UREA
  - H2O2
  - HNO3
- Radon adsorption is reduced after the treatment

Charcoal treated with HNO3 to remove Radium:

- Base charcoal is Carbio12 G90: **A(Ra) = 0,24 ± 0,04 Bq/kg**
- Carbio12 G90 treated with HNO3 : **A (Ra) < 0,16 Bq/kg**

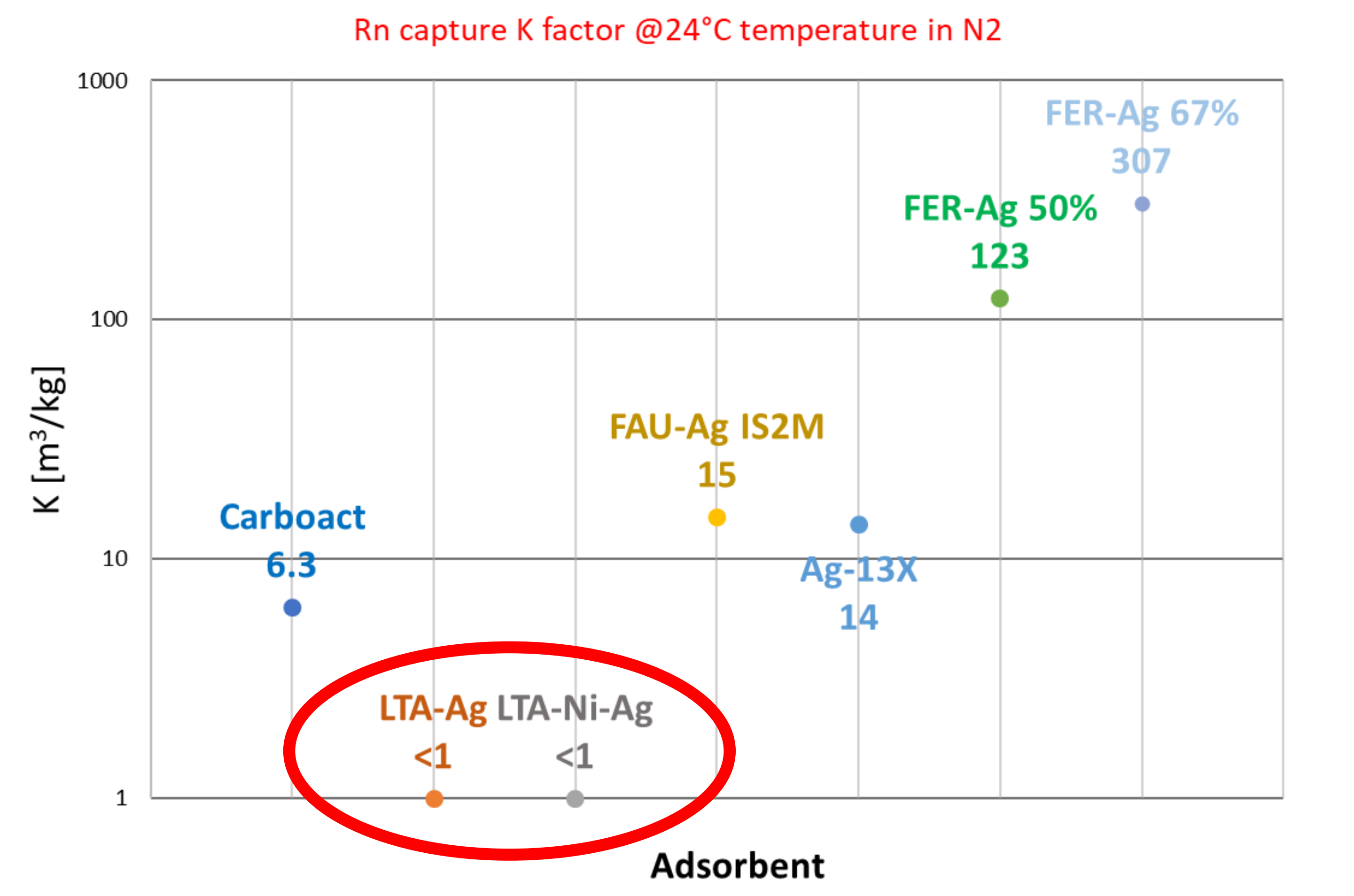
2 silver AC produced, waiting for measurment

IRENE Results

Synthesis & measurement

Zeolite synthesis:

1. LTA-Ag / LTA-Ag-Ni
2. FAU-Ag equivalent to Ag-13X
   - K(@-30°C) = 293 ± 56 m^3/kg
3. **FER-Ag exchanged at 50%:**
   - **K(@24°C) = 123 ± 16 m^3/kg**
   - <10x better than standard AC
4. **FER-Ag exchanged at 67%:**
   - **K(@24°C) = 307 ± 48 m^3/kg**
   - <30x better than standard AC



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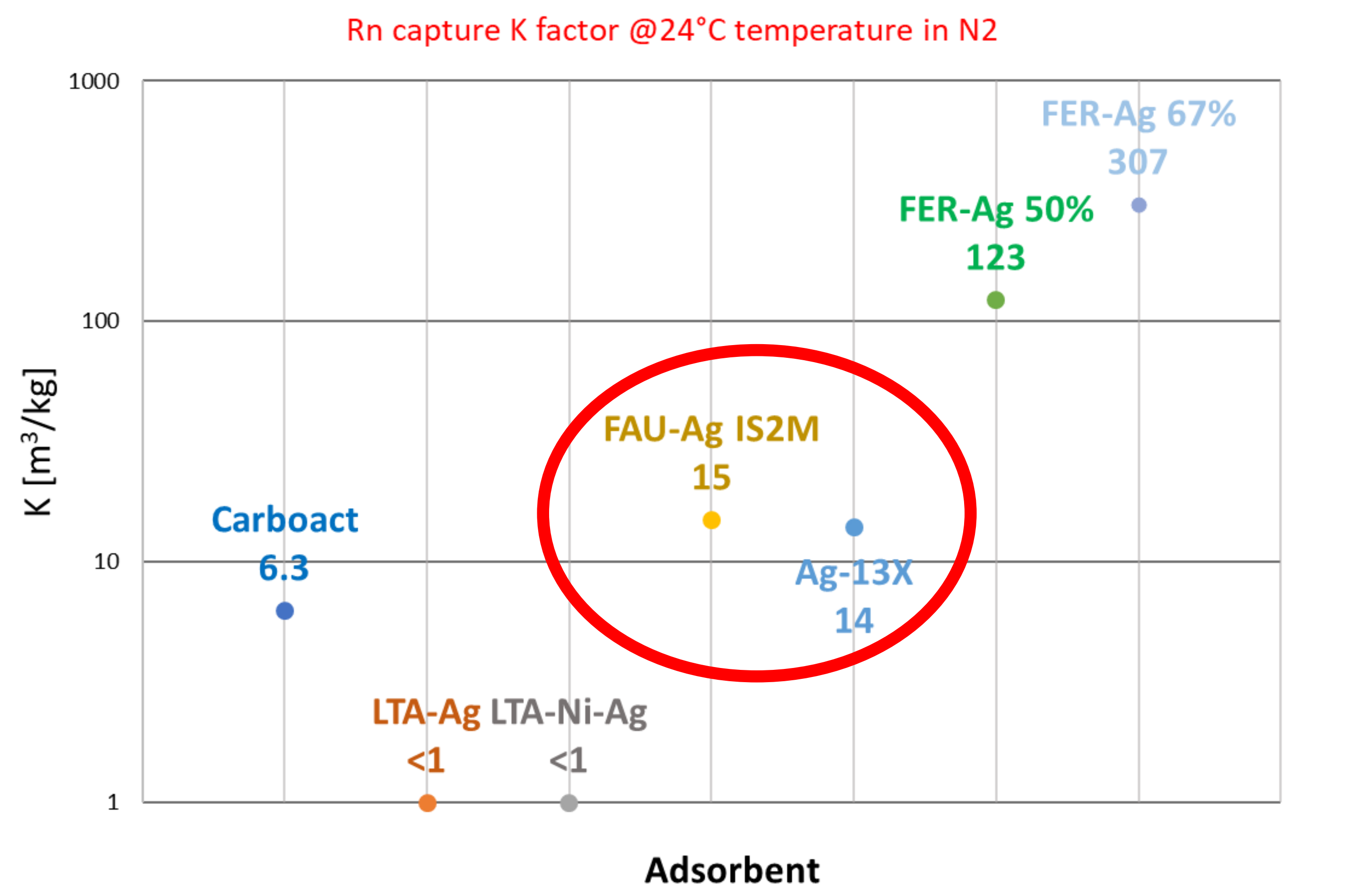

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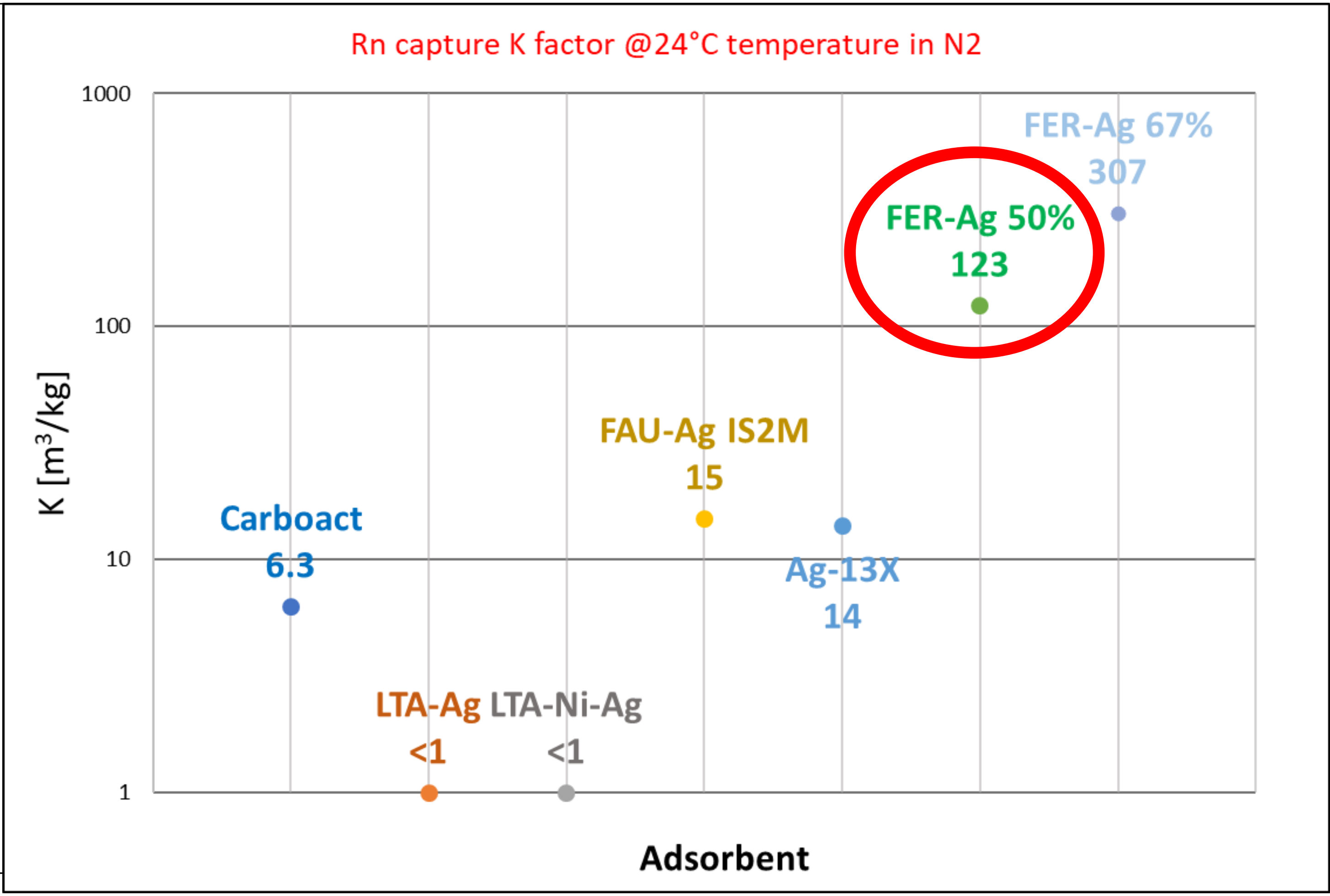

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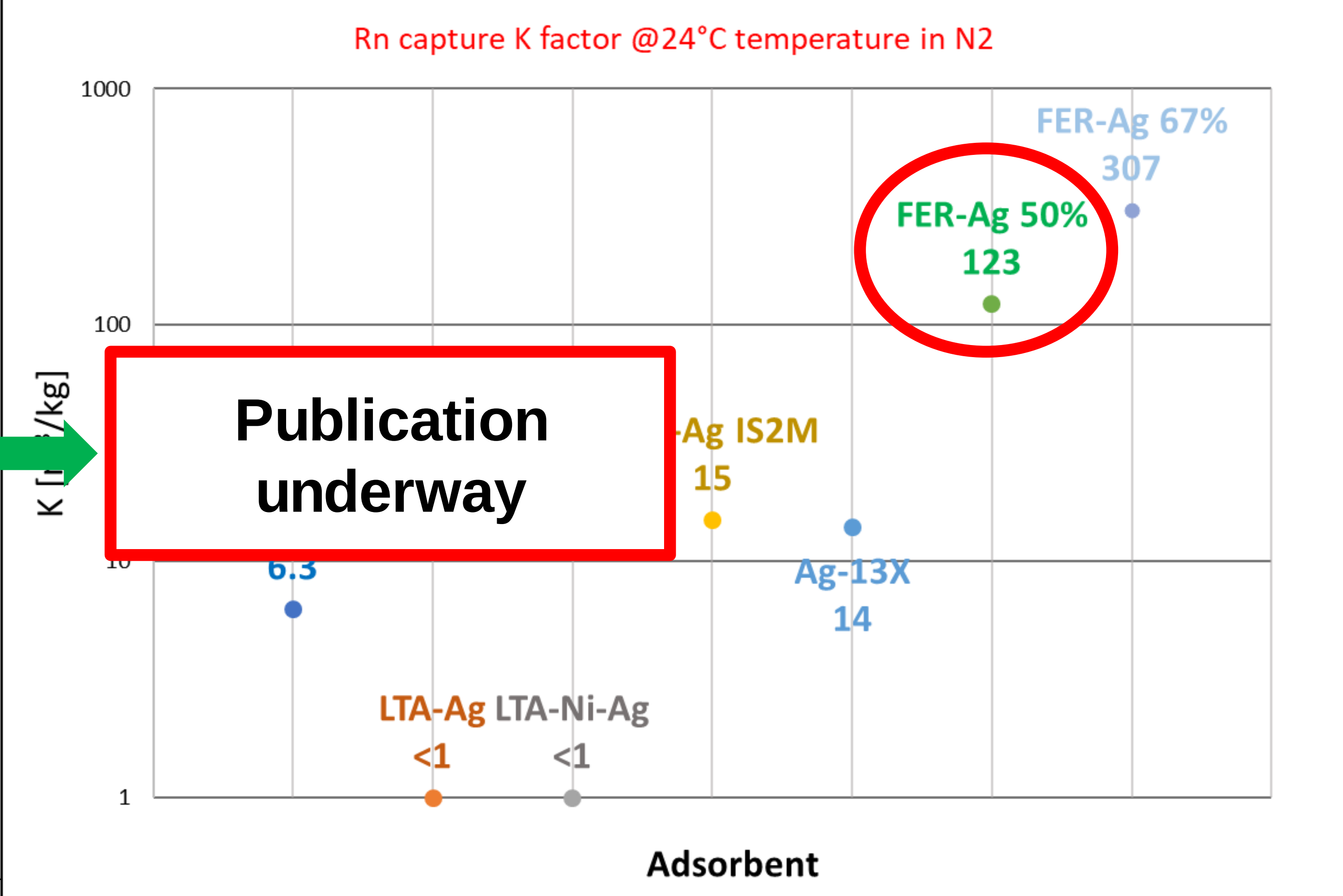

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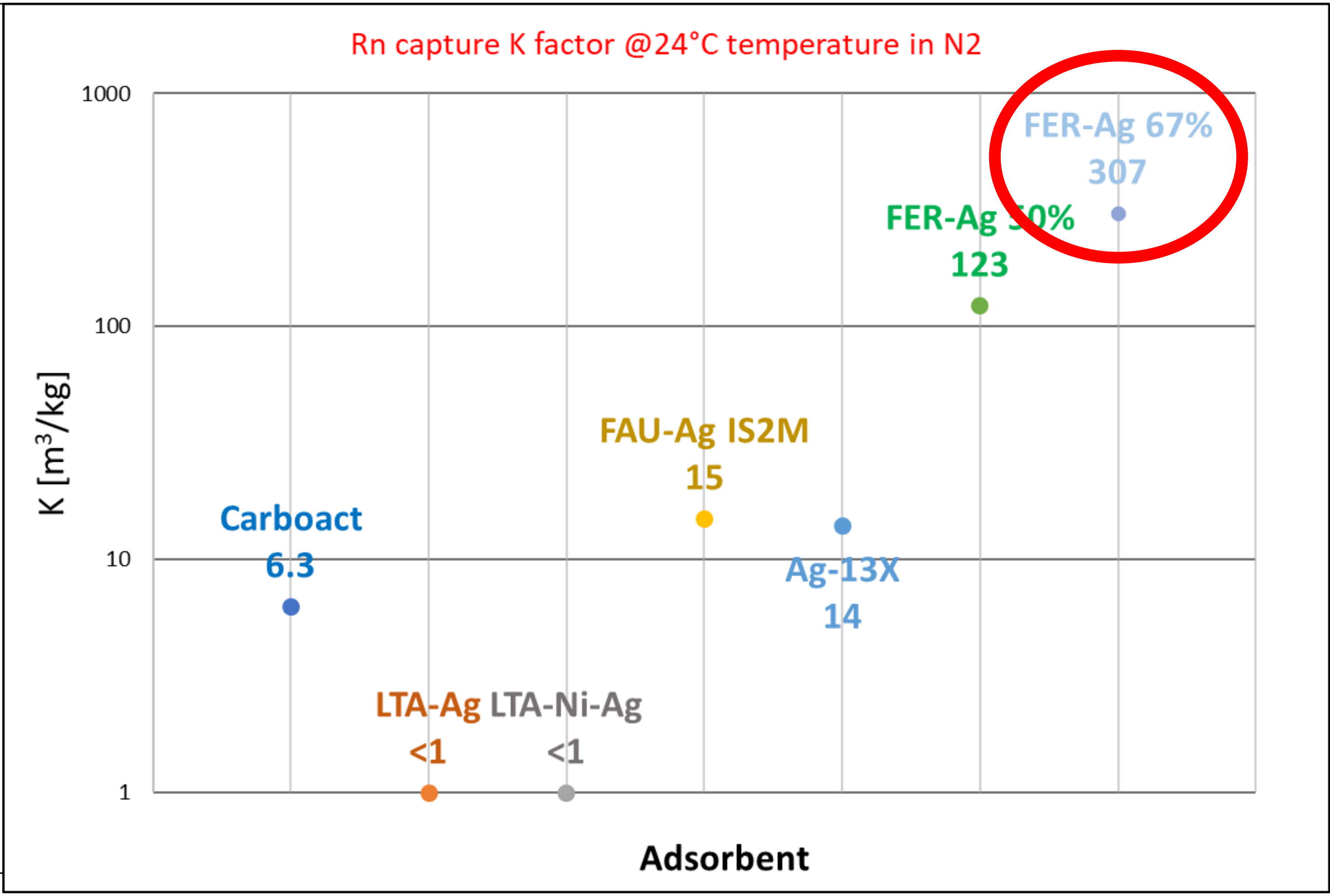
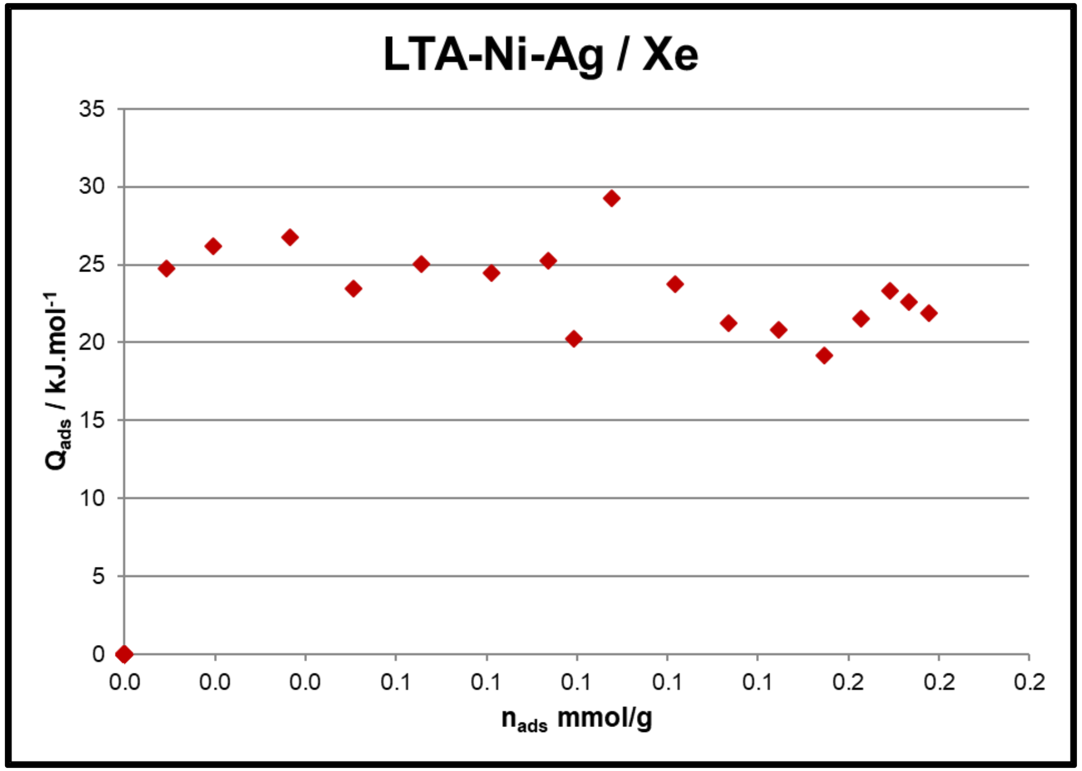
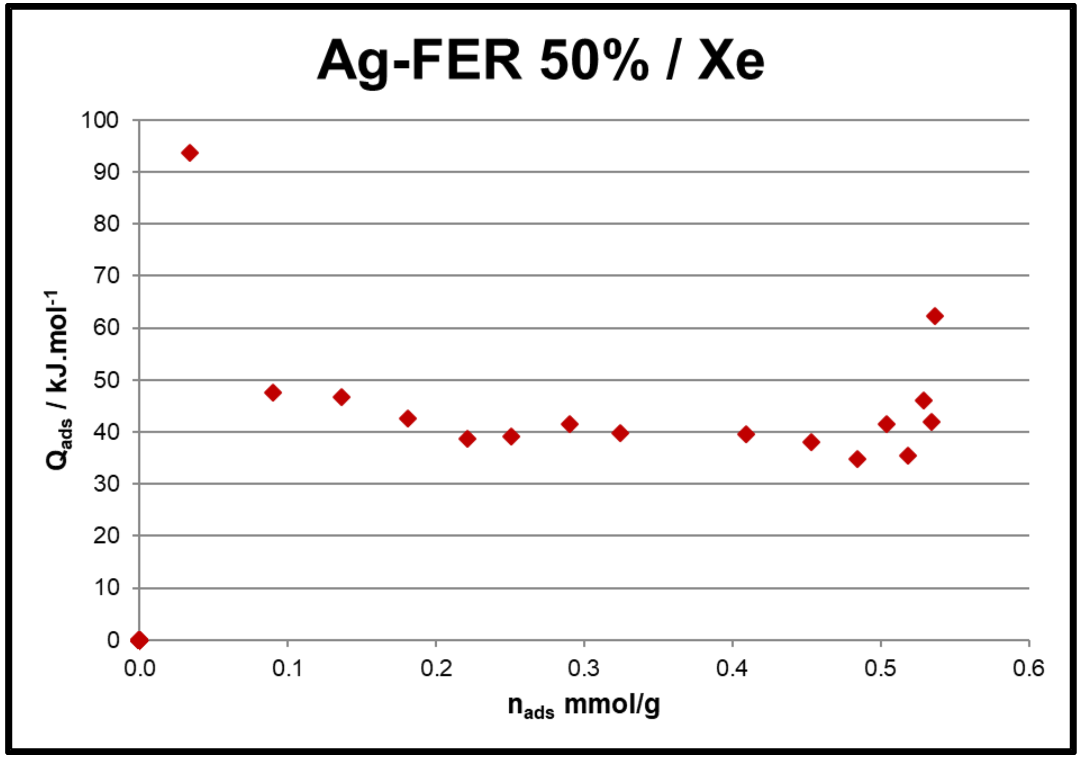


IRENE Results

Xe adsorption enthalpy measurement

Xe Adsorption enthalpy @30°C measurement for:





→ **Zeolite that adsorb well Rn adsorb also well Xe**

Conclusion

- The objective of the **IRENE** project is to tackle the problem of radon capture in microporous materials in a scientific and coherent way, thanks to a unique consortium of physical chemists and particle physicists

- **IRENE** has produced new adsorbent doped with silver and other metals while controlling all the step !

- The produced FER-Ag exchanged at 50% showed an adsorption factor **10 times** better than standard AC at room temperature and the publication is underway.

- And the FER-Ag exchanged at 67% showed an adsorption factor **30 times** better than standard AC at room temperature.

- **IRENE** is continuing to produce new adsorbent, Metal doped AC, Cryptophane and Metal doped Zeolite.

- The next step is to measure the radio purity of the produced FER-Ag.

- And also the Radon adsorption factor in Xe of those zeolite.

Thanks for your attention

Back up

Back up