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Scintillating Metal Organic Framework for radioactive gas detection

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Context

The detection of radioactive gases (RG) is of an utmost importance for radioprotection. The target gases in this project are ⁸⁵Kr, ¹³³Xe, and ³H, whose productions are mainly anthropogenic. ⁸⁵Kr and ¹³³Xe are both fission products generated by nuclear fuel reprocessing plants¹. ³H, on the other hand, is used in fusion reactors, whose implementation is predicted to increase with the upcoming ITER project².

One of the methods used for RG detection is liquid scintillation. A scintillator is a material that converts ionizing radiation into photons, which can be detected using photodetectors. Liquid scintillation, however, only allows for remote detection. Therefore, a gap for the online detection of RG exists, which is why a new class of porous scintillating materials, including Metal Organic Frameworks (MOF), are promising. The use of MOFs as scintillators for radiation detection was first experimentally demonstrated in 2009 and since then have only been theorized as potential candidates for RG detection³. We present here a library of MOF design and the first breakthrough results for RG detection.

Objectives

MOFs are the only class of porous materials to combine high surface areas of about 2000 m²g⁻¹ and a modular synthesis approach, which allows us to explore a large variety of fluorescent sponge-like materials. A solvothermal single crystal synthesis approach was chosen to ensure the purity of the MOF and hence accurate photophysical properties.

A unique gas bench experimental setup at the Laboratoire National Henri Becquerel (LNHB) is used to perform the gas detection experiments⁴. The RG is circulated through the MOF, where it is absorbed and concentrated. This maximizes the surface contact between the RG and detector material. The MOF absorbs the energy from the ionizing radiation produced by the disintegration of the RG and emits photons, which will be detected by three photomultiplier tubes in coincidence.

Results

Figure I shows the results obtained for ⁸⁵Kr detection experiment, with the blank being a measurement without MOFs and scintillating microspheres being used as a known reference material.

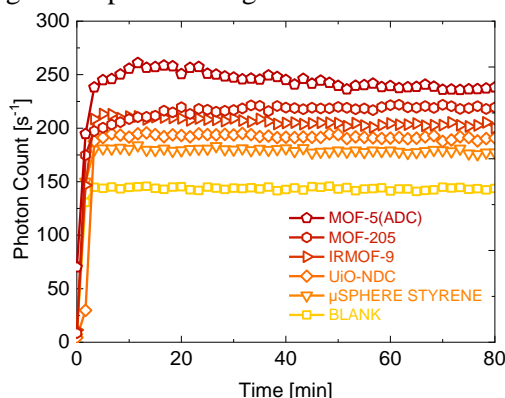


Figure I: Illustrating results for the ⁸⁵Kr detection experiment.

The MOFs are able to absorb the ⁸⁵Kr and scintillate, as proven by the higher photon count with respect to the blank. The higher the photon count, the better the performance of the MOF as a scintillator.

Conclusion

To the best of our knowledge, this is the first proof of concept where the porous and scintillating nature of MOFs have been used for radioactive gas detection. The search for MOFs producing higher scintillation yields is ongoing, as well as the improvement of the gas bench setup for accurate and reproducible metrological measurements. The next step is ³H detection which is the most challenging target due to its low energy β ionizing radiation. It is in this configuration that the porosity of MOFs will become crucial, as it will maximize beta interaction within the scintillator.

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