

6. Chemistry Nobel Prize 2025

The 2025 Nobel Prize in Chemistry has been awarded to *Susumu Kitagawa*, *Richard Robson*, and *Omar Yaghi* for pioneering Metal-Organic Frameworks (MOFs) — materials with uniquely designed porous structures that enable multiple scientific and industrial applications.

Metal-Organic Frameworks (MOFs) - Overview

Definition - MOFs are crystalline materials formed by linking metal ions (nodes) with organic carbon-based molecules (linkers), creating three-dimensional networks with highly ordered pores.

Analogy - Like a brick building versus a building made of beams and pillars, MOFs create controlled empty spaces at the molecular level for trapping and releasing molecules.

Functionality - The pores act like molecular sponges, allowing storage, capture, and controlled release of gases or liquids. MOFs combine rigid metal anchors with flexible organic linkers to create customizable molecular architectures.

Structure and Chemistry

Metal Nodes - Act as anchors or joints, providing stability and binding points.

Organic Linkers - Form rings or chains, defining the spatial arrangement and pore size.

Porosity - Highly tunable in terms of pore size, geometry, and chemical environment. Provides selective capture of molecules based on size, shape, and chemistry.

Chemical Stability - Some MOFs withstand extreme heat (up to 350°C) and harsh chemical conditions, suitable for industrial applications.

Historical Development

Richard Robson (1970s) - Conceptualized linking metal atoms with molecules rather than atoms to create expanded molecular frameworks. Early MOFs were unstable, but foundational for the field.

Susumu Kitagawa (Japan) - Stabilized frameworks and demonstrated gas permeability through MOF pores.

Omar Yaghi (1995, USA/Jordan) -

1. Created stable two-dimensional MOFs using copper or cobalt.
2. Developed the concept of "guest molecules" trapped in MOF cavities.
3. Coined the term "metal-organic framework" in a 1995 Nature publication.
4. Introduced the principle of reticular chemistry — building extended frameworks with predictable linkages.

Recognition - 2025 Nobel Prize in Chemistry awarded for the development of MOFs. Highlighted that ten of thousands of MOFs can now be designed, enabling new chemical possibilities.

Reticular Chemistry

Definition - Linking molecular building blocks into extended crystalline frameworks via strong covalent or coordination bonds.

Significance - Allows predictable assembly of frameworks. Enables custom design for specific chemical, physical, or environmental functions.

Distinctive Features of MOFs

Customisable Porosity - Pore size and shape can be tailored to target specific molecules.

Design Flexibility - Chemists can predefine the MOF's target molecules and binding conditions.

Environmental Relevance - Capture of CO₂, PFAS, or other pollutants for climate mitigation and water purification.

Chemical and Thermal Stability - Some MOFs withstand extreme conditions, making them suitable for industrial-scale applications.

Real-World Applications of MOFs

Water Harvesting - MOFs can extract water from desert air, providing sustainable water solutions for arid regions.

Pollutant Removal - Capable of filtering persistent organic pollutants (e.g., PFAS) from water.

Carbon Capture – MOFs selectively trap CO₂, helping mitigate climate change.

Hydrogen Storage – Porous structure allows safe, efficient hydrogen storage, supporting green energy transitions.

Food Preservation – Capture ethylene gas released by fruits to slow ripening and reduce spoilage.

Gas Separation & Storage – Used in industrial gas separation, storing gases like methane or oxygen efficiently.

Drug Delivery – OFs can encapsulate pharmaceuticals, releasing drugs in a controlled manner within the body.

Catalysis – MOFs serve as heterogeneous catalysts for chemical reactions due to their high surface area and tunable pores.

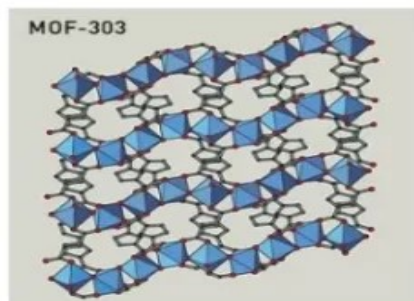
Significance and Future Prospects

MOFs are considered revolutionary materials for chemistry, environmental science, and industrial applications.

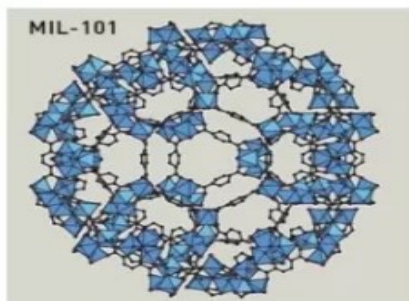
Potential Impacts –

1. Climate mitigation via CO₂ capture.
2. Sustainable water solutions in deserts.
3. Green energy adoption through hydrogen storage.
4. Pollution reduction in water and air.

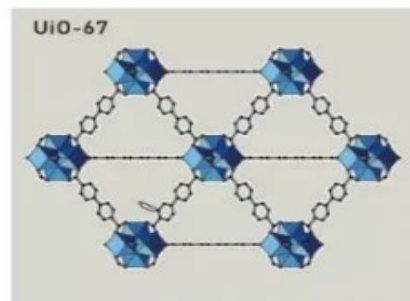
MOFs represent a new era of materials chemistry, where molecular-level design translates into real-world solutions.



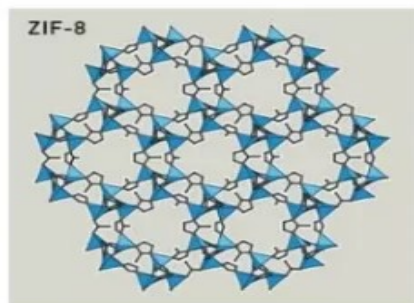
MOF-303 can capture water vapour from desert air during the night. When the sun heats up the material in the morning, potable water is released.



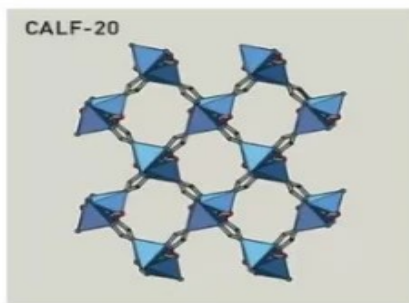
MIL-101 has gigantic cavities. It has been used to catalyse the decomposition of crude oil and antibiotics in polluted water. It can also be used to store large quantities of hydrogen or carbon dioxide.



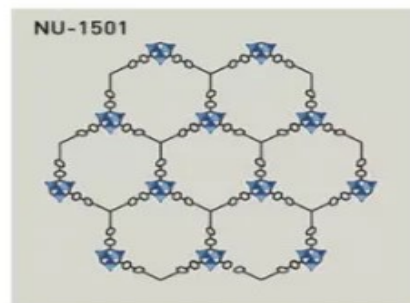
UiO-67 can absorb PFAS from water, which makes it a promising material for water treatment and the removal of pollutants.



ZIF-8 has been used experimentally for mining rare-earth elements from wastewater.



CALF-20 has an exceptional capacity to absorb carbon dioxide. It is being tested in a factory in Canada.



NU-1501 has been optimised to store and release hydrogen at normal pressure. Hydrogen can be used to fuel vehicles, but in ordinary high-pressure tanks the gas is extremely explosive.

Source; <https://www.nobelprize.org/all-nobel-prizes-2025/>