

# 🏆 Nobel Prize in Chemistry 2025 - Development of Metal-Organic Frameworks (MOFs)

## 🏆 Awarding Body:

The Royal Swedish Academy of Sciences

## 🏆 Laureates:

1. **Susumu Kitagawa** – Kyoto University, Japan
2. **Richard Robson** – University of Melbourne, Australia
3. **Omar M. Yaghi** – University of California, Berkeley, USA

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## 🏆 Award Citation:

“For the development of metal-organic frameworks (MOFs).”

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## 🏆 Context & Significance

- The laureates developed **a new class of materials** known as **Metal-Organic Frameworks (MOFs)**.
- These materials are **crystalline structures** with **large, well-defined pores** — allowing gases and other molecules to flow through them.
- Their **porous and tunable** architecture has opened new frontiers in **chemistry, materials science, and environmental technology**.

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## 🏆 What are Metal-Organic Frameworks (MOFs)?

- MOFs are **hybrid materials** made by linking **metal ions (or clusters)** with **organic molecules (ligands)**.
- The **metal ions** act as *cornerstones*, and the **organic linkers** act as *connectors* forming a **three-dimensional network**.
- These frameworks are **porous**, resembling **a sponge or molecular cage**.

- The **size, shape, and chemical properties** of the pores can be **precisely controlled**.

## Historical Development

### Year / Scientist

**1989 - Richard Robson**

### Key Contribution

Combined positively charged **copper ions** with **four-armed organic molecules** → formed a spacious, ordered crystal with cavities. (*However, it was unstable.*)

**1992-2003 - Susumu Kitagawa**

Demonstrated that **gases can flow in and out** of the frameworks; predicted that MOFs could be **flexible**.

**1995-2003 - Omar Yaghi**

Created **stable and robust MOFs**; introduced **rational design** — meaning the structure and function of MOFs can be precisely engineered for specific uses.

## Key Features of MOFs

### 1. High Porosity:

- Up to **90% of the structure** can be empty space.
- Provides an enormous **surface area** — 1 gram of MOF can have the surface area of a football field!

### 2. Customizable Architecture:

- By altering metal ions and organic linkers, MOFs can be **designed for specific tasks** (e.g., capturing CO<sub>2</sub>, storing hydrogen).

### 3. Reversible Adsorption:

- They can **absorb and release gases** repeatedly without degrading.

### 4. Stability:

- Modern MOFs (especially those developed by Yaghi) are **chemically and thermally stable**, allowing industrial applications.

## Applications of MOFs

### Field

**Environmental Protection Carbon Capture**

### Application

### Description

MOFs can **trap CO<sub>2</sub>** from industrial emissions efficiently.

Field	Application	Description
Water Sustainability	Water Harvesting from Air	Some MOFs can <b>absorb water vapor</b> from desert air and <b>release it as liquid water</b> .
Pollution Control	PFAS & Pharmaceutical Removal	MOFs can <b>filter out harmful chemicals</b> from water.
Energy Sector	Hydrogen/Methane Storage	Used for <b>safe, compact gas storage</b> in clean energy systems.
Catalysis	Chemical Reactions	Act as <b>heterogeneous catalysts</b> , speeding up reactions within their porous networks.
Sensors & Electronics	Electrical Conductivity	Some MOFs can <b>conduct electricity</b> , used in <b>chemical sensors</b> .

## ⚡ Scientific & Industrial Importance

- MOFs represent **a revolutionary shift** in material design — from **randomly porous** materials (like zeolites) to **precisely engineered** ones.
- They offer **unprecedented control** over molecular-level architecture.
- Their **multi-functionality** makes them promising for tackling **climate change, energy storage, and environmental remediation**.

## 📌 Relevance for UPSC Examination

### 1. UPSC Prelims (Science & Tech Section):

- Questions may focus on:
  - Full form and composition of **MOF**
  - **Applications** in carbon capture or water harvesting
  - Comparison with other porous materials like **zeolites**
  - **Laureates' contributions**

### Sample Question:

*Which of the following best describes Metal–Organic Frameworks (MOFs)?*

- Alloys used in renewable energy storage
- Porous crystalline materials made of metal ions and organic linkers

- (c) Nanotubes designed for DNA sequencing
- (d) Catalysts used only in petrochemical industries

**Answer:** (b)

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## 2. UPSC Mains (GS Paper III - Science & Technology):

- Possible themes:
  - Role of **nanomaterials** and **MOFs** in sustainable development
  - **Technological innovations** for **carbon capture and storage (CCS)**
  - **Scientific advancements** with global environmental impact
  - Contribution of **chemistry to sustainable technologies**

### Value Addition for Answers:

- Quote from the Nobel Committee:

“Metal-organic frameworks have enormous potential, bringing previously unforeseen opportunities for custom-made materials with new functions.”  
– Heiner Linke, Chair of the Nobel Committee for Chemistry, 2025.

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## □□ Broader Implications

- MOFs exemplify **interdisciplinary research** — chemistry, physics, materials science, and environmental engineering.
- They align with **UN Sustainable Development Goals (SDGs)**, particularly:
  - **SDG 6:** Clean Water and Sanitation
  - **SDG 7:** Affordable and Clean Energy
  - **SDG 13:** Climate Action

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## □□ Summary

- **Innovation:** Creation of customizable porous materials (MOFs).

- **Usefulness:** From **gas capture** to **clean water** and **energy storage**.
- **Global Impact:** Offers scientific tools to address **climate and environmental challenges**.
- **UPSC Relevance:** Integrates **science, technology, environment, and sustainable development** — all core UPSC themes [www.victorgrowth.com](http://www.victorgrowth.com)

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