□□ 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

□□Award Citation:

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

□□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**.

□□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	Key Contribution
1989 – Richard Robson	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_2, 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	Application	Description
Environmental Protection	**Carbon Capture**	MOFs can **trap CO_2** from industrial emissions efficiently.

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

⚡ 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)?
(a) Alloys used in renewable energy storage
(b) 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.*

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

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**

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