

A short review of the use of the terms “Metal-Organic framework” and “Coordination Polymer”

First we list a number of definitions from various sources then we present some very simple statistics from the web and from the scientific literature. Note that the term “coordination polymer” is already in the IUPAC red book on inorganic nomenclature, see:

http://www.iupac.org/publications/books/rbook/Red_Book_2005.pdf.

Definitions

Definitions and less precise general explanations of Metal-Organic Frameworks from chemistry textbooks, scientific literature (mostly reviews), chemistry magazines, general science magazines and wikipedia and wiktionary

<i>Chemistry Textbooks</i>	<i>Source and notes</i>
<p>...metal-organic frameworks (MOF) in which metal ions are linked by coordinating organic species such a carboxylates</p> <p>...</p> <p>Metal-Organic frameworks have structures that are based on bidentate or polydentate organic ligands lying between metal ions.</p> <p>...</p> <p>A second class of three-dimensionally controlled nanostructures is called metal-organic frameworks (MOFs). These frameworks are self-assembled from a careful choice of metal ions, organic ligands and/or metal-organic polyhedra (MOP).</p>	<p><i>Shriver and Atkins' Inorganic Chemistry</i>, 5th ed, 2009 Atkins, Overton, Rourke, Weller, Armstrong Oxford University Press http://ukcatalogue.oup.com/</p> <p>The first two definitions are found in the ”solid state and materials chemistry” chapter and the third in the “nanomaterials” chapter.</p> <p>No mention in the index of “coordination polymers”.</p>
<p><i>Writing about MOF-5:</i></p> <p>This is an example of a coordination network, otherwise known as a metal-organic framework. ...many of these are porous...</p>	<p><i>Chemistry³: Introducing Inorganic, Organic and Physical Chemistry</i> 1st ed, 2009 Burrows, Parsons, Price, Holman, Pilling Oxford University Press, http://ukcatalogue.oup.com/</p>
<p>Coordination polymers, also known as Metal-organic frameworks (MOFs) are metal-ligand compounds that extent “infinitely” into one , two or three dimensions, via metal-ligand bonding. The ligand must be a bridging organic group. Infinite metal-ligand assemblies where the metal-organic connectivity is interrupted by “pure inorganic” bridges, such as OH, Cl, N3, are called “organic-inorganic hydrid materials”.</p>	<p><i>Coordination Chemistry</i> 2008 Joan Ribas Gispert Wiley-VCH http://www.wiley-vch.de/ From the chapter "Crystal Engineering: Metal-organic framework (MOFs)"</p>

<i>Advanced level textbooks</i>	<i>Source and notes</i>
Metal-organic frameworks are highly versatile and tunable 3D coordination polymers that are stable at relatively high temperatures and can exist in an empty guest free state.	<i>Supramolecular Chemistry</i> 2009 Steed & Atwood Wiley
Metal-organic frameworks (MOFs) are best considered as three-dimensionally connected networks comprising nodes, which are metal cations, or di- tri- or tetra- or polynuclear metal cation clusters, linked by organic spacers, which are usually di- tri- or tetradentate ligands.	<i>Microporous framework solids</i> 2008 Paul A. Wright RSC
<i>Scientific literature</i>	<i>Source and notes</i>
Hydrothermal Synthesis of a Metal-Organic Framework Containing Large Rectangular Channels (<i>title</i>). In this article <i>Cu(4,4'-bpy)1.5.NO₃(H₂O)</i> is described as a MOF.	O. M. Yaghi and H. Li <i>J. Am. Chem. Soc.</i> , 1995 , 117, 10401-10402.
...our early efforts to build porous metal-organic frameworks (MOFs) from monodentate ditopic linkers such as 4,4'-bipyridine...	J. Kim, B. L. Chen, T. M. Reineke, H. L. Li, M. Eddaoudi, D. B. Moler, M. O'Keeffe and O. M. Yaghi, <i>J. Am. Chem. Soc.</i> , 2001 , 123, 8239-8247.
Coordination polymers, also known as metal-organic coordination networks (MOCNs) or metal-organic frameworks (MOFs), are metal-ligand compounds that extend “infinitely” into one, two or three dimensions (1D, 2D or 3D, respectively) via more or less covalent metal-ligand bonding. The ligand must be a bridging organic group. At least in one extended dimension the metal atoms must solely be bridged by this organic ligand. Furthermore, at least one carbon atom must lie between the donor atoms.	C. Janiak, <i>Dalton Trans</i> 2003 , 2781-2804
...the new area of the crystal engineering of coordination polymers, or metal-organic frameworks (MOFs).	V. A. Blatov, L. Carlucci, G. Ciani and D. M. Proserpio <i>CrystEngComm</i> 2004 , 377-395
The subject, now called reticular chemistry [2,3], is concerned largely (but in principle, not exclusively) with the synthesis and properties of metal-organic frameworks (MOFs), particularly those in which the components are linked by strong bonds such as occur in metal carboxylates. Thus it should be differentiated from, for example, the assembly of molecular crystals held together by hydrogen bonds or even the formation of “coordination polymers” in which metal atoms are coordinated with a multitopic organic component such as dipyrityl.	O. Yaghi & M. O'Keeffe, <i>J. Solid State Chemistry</i> 2005 , 178
The coordination polymers, or metal organic frameworks (MOFs) as they are also known, can be defined as extended arrays composed of isolated metal atoms or clusters that are linked by polyfunctional organic ligands, L; these are based upon M-L-M connectivity.	A. K. Cheetham, C. N. R. Rao & R. K. Feller, <i>Chem. Commun.</i> , 2006 , 4780-4795

Second, there are systems that contain extended arrays of inorganic connectivity, which we shall refer to for convenience as extended inorganic hybrids.	
Metal organic frameworks (MOFs) are a new class of hybrid material built from metal ions with well-defined coordination geometry and organic bridging ligands. They are extended structures with carefully sized cavities	Figuroa, J. D.; Fout, T.; Plasynski, S.; McIlvried, H.; Srivastava, R. D., <i>Int. J. Greenhouse Gas Contr.</i> 2008 , 2, 9-20
...link inorganic ‘joints’ with organic ‘struts’ by strong bonds to make robust and often porous MOFs featuring extended network architectures	J. Long & O. Yaghi, Editorial <i>Chem. Soc. Rev.</i> , 2009 , 38, 1213–1214
I use the term ‘MOF’ in the narrow sense of materials with frameworks built by linking polyatomic clusters (secondary building units or SBUs) entirely by strong covalent bonds and thus not including coordination polymers, which have some generally weaker bonds and lower stability, as described elsewhere in this issue. ² This seems to be now widely accepted although originally the term ‘MOF’ was applied to coordination polymers and some still apply the term ‘coordination polymer’ to MOFs, but I think the distinction is usefully made.	M. O’Keeffe, <i>Chem. Soc. Rev.</i> , 2009 , 38, 1215–1217
Coordination polymers (CPs) are solid materials formed by an extended network of metal ions (or clusters) coordinated to multidentate organic molecules. This definition encompasses a large variety of materials containing metals and organic molecules having very different characteristics, as for instance crystalline and amorphous, as well as porous and nonporous solids. The present review is dedicated to a special group of CPs referred to as metal organic frameworks (MOFs), which are crystalline and porous compounds involving strong metal-ligand interactions.[13] ... [13] Rowsell, J. L. C.; Yaghi, O. M. <i>Microporous Mesoporous Mater.</i> 2004 , 73, 3.	A. Corma, H. Garca and F. X. Llabrés i Xamena, <i>Chem. Rev.</i> 2010 , 110, 4606-4655.
<i>Chemistry Magazines and related sources</i>	
MOF crystals are metal clusters linked by organic groups to form 1-, 2- and 3-D frameworks.	<i>RSC Highlights in Chemical Technology</i> July 2008 http://www.rsc.org/Publishing/ChemTech/
...MOF compounds—crystalline materials composed of metal ions or clusters connected by way of organic linkers	<i>Chemical & Engineering News</i> Aug 2008 http://pubs.acs.org/cen/
Often dubbed molecular 'sponges' for their ability to mop up extraordinary quantities of gas or liquid in their cavernous pores, MOFs are widely thought of as gas storage materials	<i>Chemistry World</i> October 2009 http://www.rsc.org/chemistryworld/

<i>General Science Magazines</i>	
MOFs are made up of alternating organic molecules and metal-containing compounds.	<i>New Scientist</i> 04 February, 2004 http://www.newscientist.com
...metal-organic frameworks, or MOFs, which have been described as crystal sponges.	<i>ScienceDaily</i> Apr. 13, 2007 http://www.sciencedaily.com/
In MOF materials, metal ions can be connected by organic molecules to form scaffolding-like structures similar to a molecular Tinker toy. The struts that make up the framework structure do not fill space efficiently, in the way that Lego blocks might, leaving extra spaces in the structure which are capable of containing guest molecules.	<i>Science News</i> Sept, 2008 http://esciencenews.com/
Metal-organic frameworks (MOFs) are of significant interest because they can be loaded with a broad array of materials, ranging from liquid hydrogen to drug molecules	<i>sciencebusiness.net</i> 6 May 2009 http://bulletin.sciencebusiness.net/
A new class of materials with nano-scale pores... ..metal-organic frameworks act much like sponges...	<i>iSGTW</i> http://www.isgtw.org/ 23 Sept. 2009
The material ... is known as a metal organic framework (MOF), which consists of a porous cage of molecules. MOFs are not new and are of great interest because of their unique porous – or holey – structure.	<i>Energy efficiency news,</i> 19 October 2009 http://www.energyefficiencynews.com/
<i>Wiki</i>	
Metal-Organic Frameworks are crystalline compounds consisting of metal ions or clusters coordinated to often rigid organic molecules to form one-, two-, or three-dimensional structures that can be porous . In some cases, the pores are stable to elimination of the guest molecules (often solvents) and can be used for the storage of gases such as hydrogen and carbon dioxide .	http://en.wikipedia.org/wiki/Metal-organic_framework
Any of several highly porous , crystalline substances having a cage structure of metal ions coordinated to organic compounds; they have an application in the bulk storage of gases such as hydrogen	http://en.wiktionary.org/wiki/metal-organic_framework

MOFs and CPs in Chemical Abstract and Science Citation Index

Chemical Abstracts has a specific “index term” called “Organic Inorganic Hybrid Materials” but no specific “Metal-Organic Framework” index entry. Searching for “MOF” is complicated by the fact that this abbreviation more commonly means “Multiple Organ Failure”.

“Metal-Organic Framework*” gives 912 unique answers. Combining MOF and metal gives a further 1112 references and combined we have a total of 1687 unique answers.

“Coordination polymer*” gives 6794 unique answers.

167 of these answers belong to both categories, thus 10% of the MOF answers contain also the term “Coordination polymer”. A typical example:

Titel: Metal-Organic Frameworks Based on Different Benzimidazole Derivatives: Effect of Length and Substituent Groups of the Ligands on the Structures

Li, Shun-Li; Lan, Ya-Qian; Ma, Ji-Cheng; Ma, Jian-Fang; Su, Zhong-Min

Crystal Growth & Design (2010), 10(3), 1161-1170.

Abstract: *Seven coordination polymers constructed from...*

In Science Citation Index as implemented in Web of Science the situation is somewhat different. Cross-indexing of MOF and CP is here sometimes automatic because of the “keywords plus” terms used by ISI. This means that an article that cite two or more articles that contain the term “metal-organic framework” in the title will be indexed with “metal-organic framework” as a “keywords plus”.

Searching for “metal organic framework” or “metal organic frameworks” give far more hits in this database, 4418, while “coordination polymer” gives 13243. The overlap in this case is 1092 hits, or 25%.