

Organometallic Compounds Usage in Commercial Reactions, Industrial Applications: A Study

*M.Sadashiva. Associate Professor of Chemistry, G.B.R. Degree College, Hoovinahadagali.

Abstract

This paper attempts to study how **Organometallic compounds are defined as compounds containing a covalent bond between a carbon atom and a metal**. Organometallic chemistry is the study of organometallic compounds, chemical compounds containing at least one chemical bond between a carbon atom of an organic molecule and a metal, including alkaline, alkaline earth, and transition metals, and sometimes broadened to include metalloids like boron, silicon, and tin, as well. Early developments in organometallic chemistry include Louis Claude Cadet's synthesis of methyl arsenic compounds related to cacodyl, William Christopher Zeise's platinum-ethylene complex, Edward Frankland's discovery of diethyl- and dimethylzinc, Ludwig Mond's discovery of $\text{Ni}(\text{CO})_4$, and Victor Grignard's organomagnesium compounds. (Though not always acknowledged as an organometallic compound, Prussian blue, a mixed-valence iron-cyanide complex, was first prepared in 1706 by paint maker Johann Jacob Diesbach as the first coordination polymer and synthetic material containing a metal-carbon bond.) The abundant and diverse products from coal and petroleum led to Ziegler–Natta, Fischer–Tropsch, hydroformylation catalysis which employ CO, H_2 , and alkenes as feedstocks and ligands.

Recognition of organometallic chemistry as a distinct subfield culminated in the Nobel Prizes to Ernst Fischer and Geoffrey Wilkinson for work on metallocenes. In 2005, Yves Chauvin, Robert H. Grubbs and Richard R. Schrock shared the Nobel Prize for metal-catalyzed olefin metathesis. Aside from bonds to organyl fragments or molecules, bonds to 'inorganic' carbon, like carbon monoxide (metal carbonyls), cyanide, or carbide, are generally considered to be organometallic as well. Some related compounds such as transition metal hydrides and metal phosphine complexes are often included in discussions of organometallic compounds, though strictly speaking, they are not necessarily organometallic. The related but distinct term "metalorganic compound" refers to metal-containing compounds lacking direct metal-carbon bonds but which contain organic ligands. Metal β -diketonates, alkoxides, dialkylamides, and metal phosphine complexes are representative members of this class. The field of organometallic chemistry combines aspects of traditional inorganic and organic chemistry. Organometallic compounds are widely used both stoichiometrically in research and industrial chemical reactions, as well as in the role of catalysts to increase the rates of such reactions (e.g., as in uses of homogeneous catalysis), where target molecules include polymers, pharmaceuticals, and many other types of practical products.

Key words: Valence Electron Central Atom Organometallic Compounds, metal-carbon bond.

Introduction

Organometallic chemistry is the study of organometallic compounds, chemical compounds containing at least one chemical bond between a carbon atom of an organic molecule and a metal, including alkaline, alkaline earth, and transition metals, and sometimes broadened to include metalloids like boron, silicon, and selenium, as well. Aside from bonds to organyl fragments or molecules, bonds to 'inorganic' carbon, like carbon monoxide (metal carbonyls), cyanide, or carbide, are generally considered to be organometallic as well. Some related compounds such as transition metal hydrides and metal phosphine complexes are often included in discussions of organometallic compounds, though strictly speaking, they are not necessarily organometallic. The related but distinct term "metalorganic compound" refers to metal-containing compounds lacking direct metal-carbon bonds but which contain organic ligands. Metal β -diketonates, alkoxides, dialkylamides, and metal phosphine complexes are representative members of this class. The field of organometallic chemistry combines aspects of traditional inorganic and organic chemistry. Most processes involving hydrogen rely on metal-based catalysts. Whereas bulk hydrogenations, e.g. margarine production, rely on heterogeneous catalysts, For the production of fine chemicals, such hydrogenations rely on soluble organometallic complexes or involve organometallic intermediates. Organometallic complexes allow these hydrogenations to be effected asymmetrically.

Organometallic compounds are widely used both stoichiometrically in research and industrial chemical reactions, as well as in the role of catalysts to increase the rates of such reactions (e.g., as in uses of homogeneous catalysis), where target molecules include polymers, pharmaceuticals, and many other types of practical products. A constrained geometry organotitanium complex is a precatalyst for olefin polymerization.

Almost all industrial processes involving alkene-derived polymers rely on organometallic catalysts. The world's polyethylene and polypropylene are produced via both heterogeneously via Ziegler–Natta catalysis and homogeneously, e.g., via constrained geometry catalysts.

Most processes involving hydrogen rely on metal-based catalysts. Whereas bulk hydrogenations (e.g., margarine production) rely on heterogeneous catalysts, for the production of fine chemicals such hydrogenations rely on soluble (homogenous) organometallic complexes or involve organometallic intermediates. Organometallic complexes allow these hydrogenations to be effected asymmetrically.

Many semiconductors are produced from trimethylgallium, trimethylindium, trimethylaluminium, and trimethylantimony. These volatile compounds are decomposed along with ammonia, arsine, phosphine and related hydrides on a heated substrate via metalorganic vapor phase epitaxy (MOVPE) process in the production of light-emitting diodes (LEDs).

Objective:

This paper intends to explore and analyze **Organometallic Compounds** chemical compounds which contain at least one bond between a **metallic element and a carbon atom belonging to an organic molecule**. Also metalloid elements such as silicon, tin, and boron are known to form organometallic compounds which are used in some **industrial chemical reactions**.

Concepts and techniques

As in other areas of chemistry, electron counting is useful for organizing organometallic chemistry. The 18-electron rule is helpful in predicting the stabilities of organometallic complexes, for example metal carbonyls and metal hydrides. However, many organometallic compounds do not follow the 18e rule. The metal atoms in organometallic compounds are frequently described by their d electron count and oxidation state. These concepts can be used to help predict their reactivity and preferred geometry. Chemical bonding and reactivity in organometallic compounds is often discussed from the perspective of the isolobal principle.

A wide variety of physical techniques are used to determine the structure, composition, and properties of organometallic compounds. X-ray diffraction is a particularly important technique that can locate the positions of atoms within a solid compound, providing a detailed description of its structure. Other techniques like infrared spectroscopy and nuclear magnetic resonance spectroscopy are also frequently used to obtain information on the structure and bonding of organometallic compounds. Ultraviolet-visible spectroscopy is a common technique used to obtain information on the electronic structure of organometallic compounds. It is also used monitor the progress of organometallic reactions, as well as determine their kinetics. The dynamics of organometallic compounds can be studied using dynamic NMR spectroscopy. Other notable techniques include X-ray absorption spectroscopy, electron paramagnetic resonance spectroscopy, and elemental analysis.

Due to their high reactivity towards oxygen and moisture, organometallic compounds often must be handled using air-free techniques. Air-free handling of organometallic compounds typically requires the use of laboratory apparatuses such as a glovebox or Schlenk line

Distinction from coordination compounds with organic ligands

Many complexes feature coordination bonds between a metal and organic ligands. Complexes where the organic ligands bind the metal through a heteroatom such as oxygen or nitrogen are considered coordination compounds (e.g., heme A and $\text{Fe}(\text{acac})_3$). However, if any of the ligands form a direct metal-carbon (M-C) bond, then the complex is considered to be organometallic. Although the IUPAC has not formally defined the term, some

chemists use the term "metalorganic" to describe any coordination compound containing an organic ligand regardless of the presence of a direct M-C bond.

The status of compounds in which the canonical anion has a negative charge that is shared between (delocalized) a carbon atom and an atom more electronegative than carbon (e.g. enolates) may vary with the nature of the anionic moiety, the metal ion, and possibly the medium. In the absence of direct structural evidence for a carbon–metal bond, such compounds are not considered to be organometallic. For instance, lithium enolates often contain only Li-O bonds and are not organometallic, while zinc enolates (Reformatsky reagents) contain both Zn-O and Zn-C bonds, and are organometallic in nature.

Structure and properties

The metal-carbon bond in organometallic compounds is generally highly covalent. For highly electropositive elements, such as lithium and sodium, the carbon ligand exhibits carbanionic character, but free carbon-based anions are extremely rare, an example being cyanide.

Most organometallic compounds are solids at room temperature, however some are liquids such as methylcyclopentadienyl manganese tricarbonyl, or even volatile liquids such as nickel tetracarbonyl. Many organometallic compounds are air sensitive (reactive towards oxygen and moisture), and thus they must be handled under an inert atmosphere. Some organometallic compounds such as triethylaluminium are pyrophoric and will ignite on contact with air.

Organometallic compounds find wide use in commercial reactions, both as homogenous catalysts and as stoichiometric reagents. For instance, organolithium, organomagnesium, and organoaluminium compounds, examples of which are highly basic and highly reducing, are useful stoichiometrically but also catalyze many polymerization reactions.

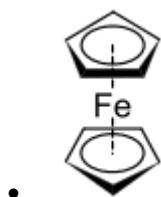
Almost all processes involving carbon monoxide rely on catalysts, notable examples being described as carbonylations. The production of acetic acid from methanol and carbon monoxide is catalyzed via metal carbonyl complexes in the Monsanto process and Cativa process. Most synthetic aldehydes are produced via hydroformylation. The bulk of the synthetic alcohols, at least those larger than ethanol, are produced by

hydrogenation of hydroformylation-derived aldehydes. Similarly, the Wacker process is used in the oxidation of ethylene to acetaldehyde.

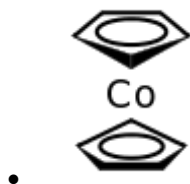
Organometallic compounds are distinguished by the prefix "organo-" (e.g., organopalladium compounds), and include all compounds which contain a bond between a metal atom and a carbon atom of an organyl group. In addition to the traditional metals (alkali metals, alkali earth metals, transition metals, and post transition metals), lanthanides, actinides, semimetals, and the elements boron, silicon, arsenic, and selenium are considered to form organometallic compounds. Examples of organometallic compounds include Gilman reagents, which contain lithium and copper, and Grignard reagents, which contain magnesium. Tetracarbonyl nickel and ferrocene are examples of organometallic compounds containing transition metals. Other examples of organometallic compounds include organolithium compounds such as n-butyllithium (n-BuLi), organozinc compounds such as diethylzinc (Et_2Zn), organotin compounds such as tributyltin hydride (Bu_3SnH), organoborane compounds such as triethylborane (Et_3B), and organoaluminium compounds such as trimethylaluminium (Me_3Al).

A naturally occurring organometallic complex is methylcobalamin (a form of Vitamin B12), which contains a cobalt-methyl bond. This complex, along with other biologically relevant complexes are often discussed within the subfield of bioorganometallic chemistry.

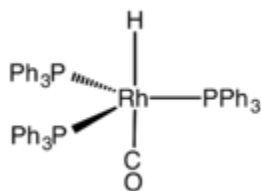
Representative Organometallic Compounds



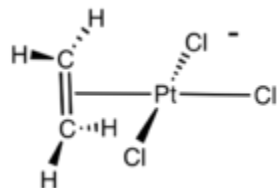
Ferrocene is an archetypal organoiron complex. It is an air-stable, sublimable compound.



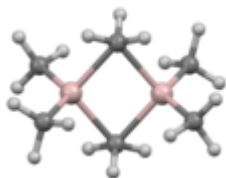
Cobaltocene is a structural analogue of ferrocene, but is highly reactive toward air.



Tris(triphenylphosphine)rhodium carbonyl hydride is used in the commercial production of many aldehyde-based fragrances.



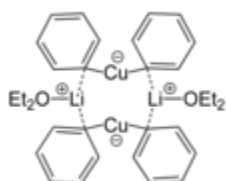
Zeise's salt is an example of a transition metal alkene complex.



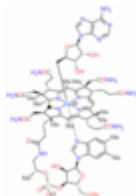
Trimethylaluminum is an organometallic compound with a bridging methyl group. It is used in the industrial production of some alcohols.



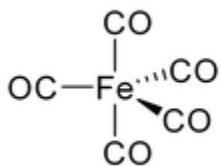
Dimethylzinc has a linear coordination. It is a volatile pyrophoric liquid that is used in the preparation of semiconducting films.



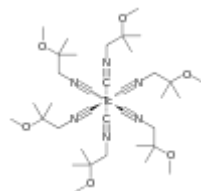
Lithium diphenylcuprate bis(diethyl etherate) is an example of a Gilman reagent, a type of organocopper complex frequently employed in organic synthesis.



Adenosylcobalamin is a cofactor required by several crucial enzymatic reactions that take place in the human body. It is a rare example of a metal (cobalt) alkyl in biology.



Iron(0) pentacarbonyl is a red-orange liquid prepared directly from the union of finely divided iron and carbon monoxide gas under pressure.



Technetium sestamibi is used to image the heart muscle in nuclear medicine.

Conclusion

Organometallic compounds find wide use in commercial reactions, both as homogeneous catalysis and as stoichiometric reagents. For instance, organolithium, organomagnesium, and organoaluminium compounds, examples of which are highly basic and highly reducing, are useful stoichiometrically, but also catalyze many polymerization reactions.

Almost all processes involving carbon monoxide rely on catalysts, notable examples being described as carbonylations. The production of acetic acid from methanol and carbon monoxide is catalyzed via metal carbonyl complexes in the Monsanto process and Cativa process. Most synthetic aldehydes are produced via hydroformylation. The bulk of the synthetic alcohols, at least those larger than ethanol, are produced by

hydrogenation of hydroformylation-derived aldehydes. Similarly, the Wacker process is used in the oxidation of ethylene to acetaldehyde.

Almost all industrial processes involving alkene-derived polymers rely on organometallic catalysts. The world's polyethylene and polypropylene are produced via both heterogeneously via Ziegler-Natta catalysis and homogeneously, e.g., via constrained geometry catalysts.

References

1. M. Riordan (1987). *The Hunting of the Quark: A True Story of Modern Physics*. Simon & Schuster. p. 210. ISBN 978-0-671-50466-3.
2. Rolnick, William B. (2003). *Remnants Of The Fall: Revelations Of Particle Secrets*. World Scientific Pub Co Inc. p. 136. ISBN 978-9812380609. Retrieved 14 October 2018. quark keats truth beauty.
3. Mee, Nicholas (2012). *Higgs Force: Cosmic Symmetry Shattered*. Quantum Wave Publishing. ISBN 978-0957274617. Retrieved 14 October 2018.
4. Gooden, Philip (2016). *May We Borrow Your Language?: How English Steals Words From All Over the World*. Head of Zeus. ISBN 978-1784977986. Retrieved 14 October 2018.
5. F. Close (2006). *The New Cosmic Onion*. CRC Press. p. 133. ISBN 978-1-58488-798-0.
6. J. T. Volk; et al. (1987). "Letter of Intent for a Tevatron Beauty Factory" (PDF). Fermilab Proposal #783.
7. C. Quigg (2006). "Particles and the Standard Model". In G. Fraser (ed.). *The New Physics for the Twenty-First Century*. Cambridge University Press. p. 91. ISBN 978-0-521-81600-7.
8. "The Standard Model of Particle Physics". BBC. 2002. Retrieved 19 April 2009.
9. F. Close (2006). *The New Cosmic Onion*. CRC Press. pp. 80–90. ISBN 978-1-58488-798-0.
10. D. Lincoln (2004). *Understanding the Universe*. World Scientific. p. 116. ISBN 978-981-238-705-9.
11. "Weak Interactions". Virtual Visitor Center. Stanford Linear Accelerator Center. 2008. Retrieved 28 September 2008.
12. K. Nakamura; et al. (Particle Data Group) (2010). "Review of Particle Physics: The CKM Quark-Mixing Matrix" (PDF). *Journal of Physics G*. 37 (7A): 075021. Bibcode:2010JPhG...37g5021N. doi:10.1088/0954-3899/37/7A/075021.
13. Z. Maki; M. Nakagawa; S. Sakata (1962). "Remarks on the Unified Model of Elementary Particles". *Progress of Theoretical Physics*. 28 (5): 870. Bibcode:1962PTPh..28..870M. doi:10.1143/PTP.28.870.

14. B. C. Chauhan; M. Picariello; J. Pulido; E. Torrente-Lujan (2007). "Quark–Lepton Complementarity, Neutrino and Standard Model Data Predict θ_{PMNS}
15. $13 = 9^\circ + 1^\circ$
16. -2° ". European Physical Journal. C50 (3): 573–578. arXiv:hep-ph/0605032. Bibcode:2007EPJC...50..573C. doi:10.1140/epjc/s10052-007-0212-z. S2CID 118107624.
17. R. Nave. "The Color Force". HyperPhysics. Georgia State University, Department of Physics and Astronomy. Retrieved 26 April 2009.
18. B. A. Schumm (2004). Deep Down Things. Johns Hopkins University Press. pp. 131–132. ISBN 978-0-8018-7971-5.
19. Part III of M. E. Peskin; D. V. Schroeder (1995). An Introduction to Quantum Field Theory. Addison–Wesley. ISBN 978-0-201-50397-5.
20. V. Icke (1995). The Force of Symmetry. Cambridge University Press. p. 216. ISBN 978-0-521-45591-6.
21. M. Y. Han (2004). A Story of Light. World Scientific. p. 78. ISBN 978-981-256-034-6.
22. C. Sutton. "Quantum Chromodynamics (physics)". Encyclopædia Britannica Online. Retrieved 12 May 2009.
23. A. Watson (2004). The Quantum Quark. Cambridge University Press. pp. 285–286. ISBN 978-0-521-82907-6.
24. K. A. Olive; et al. (Particle Data Group) (2014). "Review of Particle Physics". Chinese Physics C. 38 (9): 1–708. Bibcode:2014ChPhC...38i0001O. doi:10.1088/1674-1137/38/9/090001. PMID 10020536.
25. W. Weise; A. M. Green (1984). Quarks and Nuclei. World Scientific. pp. 65–66. ISBN 978-9971-966-61-4.
26. D. McMahon (2008). Quantum Field Theory Demystified. McGraw–Hill. p. 17. ISBN 978-0-07-154382-8.
27. S. G. Roth (2007). Precision Electroweak Physics at Electron–Positron Colliders. Springer. p. VI. ISBN 978-3-540-35164-1.
28. Smaller than Small: Looking for Something New With the LHC by Don Lincoln PBS Nova blog 28 October 2014
29. R. P. Feynman (1985). QED: The Strange Theory of Light and Matter (1st ed.). Princeton University Press. pp. 136–137. ISBN 978-0-691-08388-9.
30. M. Veltman (2003). Facts and Mysteries in Elementary Particle Physics. World Scientific. pp. 45–47. ISBN 978-981-238-149-1.
31. F. Wilczek; B. Devine (2006). Fantastic Realities. World Scientific. p. 85. ISBN 978-981-256-649-2.

32. F. Wilczek; B. Devine (2006). *Fantastic Realities*. World Scientific. pp. 400ff. ISBN 978-981-256-649-2.
33. M. Veltman (2003). *Facts and Mysteries in Elementary Particle Physics*. World Scientific. pp. 295–297. ISBN 978-981-238-149-1.
34. T. Yulsman (2002). *Origin*. CRC Press. p. 55. ISBN 978-0-7503-0765-9.
35. Particle Data Group (1 June 2018). "Top quark" (PDF). *Progress of Theoretical and Experimental Physics*. 2018: 083C01.
36. J. Steinberger (2005). *Learning about Particles*. Springer. p. 130. ISBN 978-3-540-21329-1.
37. C.-Y. Wong (1994). *Introduction to High-energy Heavy-ion Collisions*. World Scientific. p. 149. ISBN 978-981-02-0263-7.
38. S. B. Rüester; V. Werth; M. Buballa; I. A. Shovkovy; D. H. Rischke (2005). "The Phase Diagram of Neutral Quark Matter: Self-consistent Treatment of Quark Masses". *Physical Review D*. 72 (3): 034003. arXiv:hep-ph/0503184. Bibcode:2005PhRvD..72c4004R. doi:10.1103/PhysRevD.72.034004. S2CID 10487860.
39. M. G. Alford; K. Rajagopal; T. Schaefer; A. Schmitt (2008). "Color Superconductivity in Dense Quark Matter". *Reviews of Modern Physics*. 80 (4): 1455–1515. arXiv:0709.4635. Bibcode:2008RvMP...80.1455A. doi:10.1103/RevModPhys.80.1455. S2CID 14117263.
40. S. Mrowczynski (1998). "Quark–Gluon Plasma". *Acta Physica Polonica B*. 29 (12): 3711. arXiv:nucl-th/9905005. Bibcode:1998AcPPB..29.3711M.
41. Z. Fodor; S. D. Katz (2004). "Critical Point of QCD at Finite T and μ , Lattice Results for Physical Quark Masses". *Journal of High Energy Physics*. 2004 (4): 50. arXiv:hep-lat/0402006. Bibcode:2004JHEP...04..050F. doi:10.1088/1126-6708/2004/04/050.
42. U. Heinz; M. Jacob (2000). "Evidence for a New State of Matter: An Assessment of the Results from the CERN Lead Beam Programme". arXiv:nucl-th/0002042.
43. "RHIC Scientists Serve Up "Perfect" Liquid". Brookhaven National Laboratory. 2005. Archived from the original on 15 April 2013. Retrieved 22 May 2009.
44. T. Yulsman (2002). *Origins: The Quest for Our Cosmic Roots*. CRC Press. p. 75. ISBN 978-0-7503-0765-9.
45. A. Sedrakian; J. W. Clark; M. G. Alford (2007). *Pairing in Fermionic Systems*. World Scientific. pp. 2–3. ISBN 978-981-256-907-3.