Noble metal

From Wikipedia, the free encyclopedia

<https://en.wikipedia.org/wiki/Noble_metal> Accessed on 10th June 2020

[Jump to navigation](https://en.wikipedia.org/wiki/Noble_metal#mw-head)[Jump to search](https://en.wikipedia.org/wiki/Noble_metal#p-search)

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Noble metals in the**[**periodic table**](https://en.wikipedia.org/wiki/Periodic_table) | | | | | | | | | | | | | | | | | | |
| H |  | | | | | | | | | | | | | | | | | He |
| Li | Be |  | | | | | | | | | | | B | C | N | O | F | Ne |
| Na | Mg |  | | | | | | | | | | | Al | Si | P | S | Cl | Ar |
| K | Ca | Sc |  | **Ti** | **V** | **Cr** | Mn | Fe | Co | Ni | **Cu** | Zn | Ga | Ge | **As** | **Se** | Br | Kr |
| Rb | Sr | Y |  | **Zr** | **Nb** | **Mo** | **Tc** | **Ru** | **Rh** | **Pd** | **Ag** | Cd | In | Sn | **Sb** | **Te** | I | Xe |
| Cs | Ba | La | 1 asterisk | **Hf** | **Ta** | **W** | **Re** | **Os** | **Ir** | **Pt** | **Au** | **Hg** | Tl | Pb | **Bi** | **Po** | **At** | Rn |
| Fr | Ra | Ac | 1 asterisk | Rf | Db | Sg | Bh | Hs | Mt | Ds | Rg | Cn | Nh | Fl | Mc | Lv | Ts | Og |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  | 1 asterisk | Ce | Pr | Nd | Pm | Sm | Eu | Gd | Tb | Dy | Ho | Er | Tm | Yb | Lu |  |
|  |  |  | 1 asterisk | Th | Pa | U | Np | Pu | Am | Cm | Bk | Cf | Es | Fm | Md | No | Lr |  |
| [Refractory metals](https://en.wikipedia.org/wiki/Refractory_metal) | | | | | | | | | | | | | | | | | | |
| [Platinum group](https://en.wikipedia.org/wiki/Platinum_group) | | | | | | | | | | | | | | | | | | |
| Other [precious](https://en.wikipedia.org/wiki/Precious_metal) and semi-precious metals | | | | | | | | | | | | | | | | | | |
| Non-precious unreactive metals (including metalloids) | | | | | | | | | | | | | | | | | | |
| Radioactive unreactive metals | | | | | | | | | | | | | | | | | | |
| Radioactive, presumed unreactive metals | | | | | | | | | | | | | | | | | | |

In [chemistry](https://en.wikipedia.org/wiki/Chemistry), the **noble metals** are [metals](https://en.wikipedia.org/wiki/Metal) that are resistant to [corrosion](https://en.wikipedia.org/wiki/Corrosion) and [oxidation](https://en.wikipedia.org/wiki/Oxidation) in moist air (unlike most [base metals](https://en.wikipedia.org/wiki/Base_metal)). The short list of chemically noble metals (those elements upon which almost all [chemists](https://en.wikipedia.org/wiki/Chemist) agree) comprises [ruthenium](https://en.wikipedia.org/wiki/Ruthenium) (Ru), [rhodium](https://en.wikipedia.org/wiki/Rhodium) (Rh), [palladium](https://en.wikipedia.org/wiki/Palladium) (Pd), [silver](https://en.wikipedia.org/wiki/Silver) (Ag), [osmium](https://en.wikipedia.org/wiki/Osmium) (Os), [iridium](https://en.wikipedia.org/wiki/Iridium) (Ir), [platinum](https://en.wikipedia.org/wiki/Platinum) (Pt), and [gold](https://en.wikipedia.org/wiki/Gold) (Au).[[1]](https://en.wikipedia.org/wiki/Noble_metal#cite_note-1)

More inclusive lists include one or more of [mercury](https://en.wikipedia.org/wiki/Mercury_(element)) (Hg),[[2]](https://en.wikipedia.org/wiki/Noble_metal#cite_note-2)[[3]](https://en.wikipedia.org/wiki/Noble_metal#cite_note-3)[[4]](https://en.wikipedia.org/wiki/Noble_metal#cite_note-4) [rhenium](https://en.wikipedia.org/wiki/Rhenium) (Re),[[5]](https://en.wikipedia.org/wiki/Noble_metal#cite_note-5) and [copper](https://en.wikipedia.org/wiki/Copper) (Cu) as noble metals. On the other hand, [titanium](https://en.wikipedia.org/wiki/Titanium) (Ti), [niobium](https://en.wikipedia.org/wiki/Niobium) (Nb), and [tantalum](https://en.wikipedia.org/wiki/Tantalum) (Ta) are not included as noble metals although they are very resistant to corrosion.

[](https://en.wikipedia.org/wiki/File:Edelmetalle.jpg)

A [collection](https://en.wikipedia.org/wiki/Element_collecting) of the noble metals, including copper, rhenium and mercury, which are included by some definitions. These are arranged according to their position in the [periodic table](https://en.wikipedia.org/wiki/Periodic_table).

While the noble metals tend to be valuable – due to both their rarity in the [Earth's crust](https://en.wikipedia.org/wiki/Earth%27s_crust) and their applications in areas like [metallurgy](https://en.wikipedia.org/wiki/Metallurgy), [high technology](https://en.wikipedia.org/wiki/High_technology), and ornamentation ([jewelry](https://en.wikipedia.org/wiki/Jewelry), art, sacred objects, etc.) – the terms *noble metal* and [*precious metal*](https://en.wikipedia.org/wiki/Precious_metal) are not synonymous.

The term *noble metal* can be traced back to at least the late 14th century[[6]](https://en.wikipedia.org/wiki/Noble_metal#cite_note-6) and has slightly different meanings in different fields of study and application. Only in [atomic physics](https://en.wikipedia.org/wiki/Atomic_physics) is there a strict definition, which includes only copper, silver, and gold, because they have completely filled d-[subshells](https://en.wikipedia.org/wiki/Electron_shell#Subshells). For this reason, there are many quite different lists of "noble metals".

In addition to this term's function as a compound [noun](https://en.wikipedia.org/wiki/Noun), there are circumstances where *noble* is used as an adjective for the noun *metal*. A [galvanic series](https://en.wikipedia.org/wiki/Galvanic_series) is a hierarchy of metals (or other electrically conductive materials, including composites and [semimetals](https://en.wikipedia.org/wiki/Semimetal)) that runs from noble to active, and allows one to predict how materials will interact in the environment used to generate the series. In this sense of the word, [graphite](https://en.wikipedia.org/wiki/Graphite) is more noble than silver and the relative nobility of many materials is highly dependent upon context, as for [aluminium](https://en.wikipedia.org/wiki/Aluminium) and [stainless steel](https://en.wikipedia.org/wiki/Stainless_steel) in conditions of varying [pH](https://en.wikipedia.org/wiki/PH).[[7]](https://en.wikipedia.org/wiki/Noble_metal#cite_note-7)



**Contents**

* [1Properties](https://en.wikipedia.org/wiki/Noble_metal#Properties)
* [2Physics](https://en.wikipedia.org/wiki/Noble_metal#Physics)
* [3Electrochemistry](https://en.wikipedia.org/wiki/Noble_metal#Electrochemistry)
* [4See also](https://en.wikipedia.org/wiki/Noble_metal#See_also)
* [5References](https://en.wikipedia.org/wiki/Noble_metal#References)
* [6External links](https://en.wikipedia.org/wiki/Noble_metal#External_links)

Properties[[edit](https://en.wikipedia.org/w/index.php?title=Noble_metal&action=edit&section=1)]

Platinum, gold and mercury can be dissolved in [aqua regia](https://en.wikipedia.org/wiki/Aqua_regia), a highly concentrated mixture of [hydrochloric acid](https://en.wikipedia.org/wiki/Hydrochloric_acid) and [nitric acid](https://en.wikipedia.org/wiki/Nitric_acid), but iridium cannot. The solubility of silver is limited by the formation of silver chloride precipitate.[[8]](https://en.wikipedia.org/wiki/Noble_metal#cite_note-WM2017-8) Palladium and silver are, however, soluble in [nitric acid](https://en.wikipedia.org/wiki/Nitric_acid). Ruthenium can be dissolved in aqua regia only when in the presence of oxygen, while rhodium must be in a fine pulverized form. Niobium and tantalum are resistant to all acids, including aqua regia.[[9]](https://en.wikipedia.org/wiki/Noble_metal#cite_note-HW2001-9)

Physics[[edit](https://en.wikipedia.org/w/index.php?title=Noble_metal&action=edit&section=2)]

In physics, the definition of a noble metal is most strict. It requires that the [d-bands](https://en.wikipedia.org/wiki/Atomic_orbital) of the [electronic structure](https://en.wikipedia.org/wiki/Electronic_band_structure) be filled. From this perspective, only copper, silver and gold are noble metals, as all d-like bands are filled and do not cross the [Fermi level](https://en.wikipedia.org/wiki/Fermi_level).[[10]](https://en.wikipedia.org/wiki/Noble_metal#cite_note-10) However, d-hybridized bands do cross the Fermi level to a small extent. In the case of platinum, two d bands cross the Fermi level, changing its chemical behaviour such that it can function as a [catalyst](https://en.wikipedia.org/wiki/Catalysis). The difference in reactivity can easily be seen during the preparation of clean metal surfaces in an [ultra-high vacuum](https://en.wikipedia.org/wiki/Ultra-high_vacuum): surfaces of "physically defined" noble metals (e.g., gold) are easy to clean and keep clean for a long time, while those of platinum or palladium, for example, are covered by [carbon monoxide](https://en.wikipedia.org/wiki/Carbon_monoxide) very quickly.[[11]](https://en.wikipedia.org/wiki/Noble_metal#cite_note-11)

Electrochemistry[[edit](https://en.wikipedia.org/w/index.php?title=Noble_metal&action=edit&section=3)]

Metallic elements, including metalloids (metals usually considered noble bolded, predictions for superheavy elements italicised):[[12]](https://en.wikipedia.org/wiki/Noble_metal#cite_note-12)[[13]](https://en.wikipedia.org/wiki/Noble_metal#cite_note-Haire-13)

| **Element** | **Atomic number** | **Group** | **Period** | **Reaction** | **Potential** | **Electron configuration** |
| --- | --- | --- | --- | --- | --- | --- |
| [*Copernicium*](https://en.wikipedia.org/wiki/Copernicium) | 112 | 12 | 7 | Cn2+  + 2 e− → Cn | 2.1 V | [Rn]5f146d107s2 |
| [*Roentgenium*](https://en.wikipedia.org/wiki/Roentgenium) | 111 | 11 | 7 | Rg3+  + 3 e− → Rg | 1.9 V | [Rn]5f146d97s2 |
| [*Darmstadtium*](https://en.wikipedia.org/wiki/Darmstadtium) | 110 | 10 | 7 | Ds2+  + 2 e− → Ds | 1.7 V | [Rn]5f146d87s2 |
| [**Gold**](https://en.wikipedia.org/wiki/Gold) | 79 | 11 | 6 | Au3+  + 3 e− → Au | 1.5 V | [Xe]4f145d106s1 |
| [Astatine](https://en.wikipedia.org/wiki/Astatine) | 85 | 17 | 6 | At+  + e− → At | 1.0 V | [Xe]4f145d106s26p5 |
| [**Platinum**](https://en.wikipedia.org/wiki/Platinum) | 78 | 10 | 6 | PtO + 2 H+  + 2 e− → Pt + H 2O | 0.98 V | [Xe]4f145d96s1 |
| [**Palladium**](https://en.wikipedia.org/wiki/Palladium) | 46 | 10 | 5 | Pd2+  + 2 e− → Pd | 0.915 V | [Kr]4d105s0 |
| [*Flerovium*](https://en.wikipedia.org/wiki/Flerovium) | 114 | 14 | 7 | Fl2+  + 2 e− → Fl | 0.9 V | [Rn]5f146d107s27p2 |
| [*Meitnerium*](https://en.wikipedia.org/wiki/Meitnerium) | 109 | 9 | 7 | Mt3+  + 3 e− → Mt | 0.8 V | [Rn]5f146d77s2 |
| [**Silver**](https://en.wikipedia.org/wiki/Silver) | 47 | 11 | 5 | Ag+  + e− → Ag | 0.7993 V | [Kr]4d105s1 |
| [Mercury](https://en.wikipedia.org/wiki/Mercury_(element)) | 80 | 12 | 6 | Hg2+ 2 + 2 e−→ 2 Hg | 0.7925 V | [Xe]4f145d106s2 |
| [Selenium](https://en.wikipedia.org/wiki/Selenium) | 34 | 16 | 4 | H 2SeO 3 + 4 H+  + 4 e− → Se + 3 H 2O | 0.739 V | [Ar]3d104s24p4 |
| [**Iridium**](https://en.wikipedia.org/wiki/Iridium) | 77 | 9 | 6 | IrO 2 + 4 H+  + 4 e− → Ir + 2 H 2O | 0.73 V | [Xe]4f145d76s2 |
| [**Osmium**](https://en.wikipedia.org/wiki/Osmium) | 76 | 8 | 6 | OsO 2 + 4 H+  + 4 e− → Os + 2 H 2O | 0.65 V | [Xe]4f145d66s2 |
| [Polonium](https://en.wikipedia.org/wiki/Polonium) | 84 | 16 | 6 | Po2+  + 2 e− → Po | 0.6 V | [Xe]4f145d106s26p4 |
| [*Nihonium*](https://en.wikipedia.org/wiki/Nihonium) | 113 | 13 | 7 | Nh+  + e− → Nh | 0.6 V | [Rn]5f146d107s27p1 |
| [**Rhodium**](https://en.wikipedia.org/wiki/Rhodium) | 45 | 9 | 5 | Rh2+  + 2 e− → Rh | 0.60 V | [Kr]4d85s1 |
| [**Ruthenium**](https://en.wikipedia.org/wiki/Ruthenium) | 44 | 8 | 5 | Ru3+  + 3 e− → Ru | 0.60 V | [Kr]4d75s1 |
| [Tellurium](https://en.wikipedia.org/wiki/Tellurium) | 52 | 16 | 5 | TeO 2 + 4 H+  + 4 e− → Te + 2 H 2O | 0.57 V | [Kr]4d105s25p4 |
| [*Hassium*](https://en.wikipedia.org/wiki/Hassium) | 108 | 8 | 7 | Hs4+  + 4 e− → Hs | 0.4 V | [Rn]5f146d67s2 |
| [Copper](https://en.wikipedia.org/wiki/Copper) | 29 | 11 | 4 | Cu2+  + 2 e− → Cu | 0.339 V | [Ar]3d104s1 |
| [Bismuth](https://en.wikipedia.org/wiki/Bismuth) | 83 | 15 | 6 | Bi3+  + 3 e− → Bi | 0.308 V | [Xe]4f145d106s26p3 |
| [Rhenium](https://en.wikipedia.org/wiki/Rhenium) | 75 | 7 | 6 | ReO 2 + 4 H+  + 4 e− → Re + 2 H 2O | 0.276 V | [Xe]4f145d56s2 |
| [Technetium](https://en.wikipedia.org/wiki/Technetium) | 43 | 7 | 5 | TcO 2 + 4 H+  + 4 e− → Tc + 2 H 2O | 0.272 V | [Kr]4d55s2 |
| [Arsenic](https://en.wikipedia.org/wiki/Arsenic) | 33 | 15 | 4 | As 4O 6 + 12 H+  + 12 e− → 4 As + 6 H 2O | 0.24 V | [Ar]3d104s24p3 |
| [Antimony](https://en.wikipedia.org/wiki/Antimony) | 51 | 15 | 5 | Sb 2O 3 + 6 H+  + 6 e− → 2 Sb + 3 H 2O | 0.147 V | [Kr]4d105s25p3 |
| [*Livermorium*](https://en.wikipedia.org/wiki/Livermorium) | 116 | 16 | 7 | Lv2+  + 2 e− → Lv | 0.1 V | [Rn]5f146d107s27p4 |
| [*Bohrium*](https://en.wikipedia.org/wiki/Bohrium) | 107 | 7 | 7 | Bh5+  + 5 e− → Bh | 0.1 V | [Rn]5f146d57s2 |

The columns *group* and *period* denote its position in the [periodic table](https://en.wikipedia.org/wiki/Periodic_table), hence electronic configuration. The simplified *reaction*s, listed in the next column, can also be read in detail from the [Pourbaix diagrams](https://en.wikipedia.org/wiki/Pourbaix_diagram" \o "Pourbaix diagram) of the considered element in water. Finally the column *potential* indicates the [electric potential](https://en.wikipedia.org/wiki/Standard_electrode_potential) of the element measured against a [Standard hydrogen electrode](https://en.wikipedia.org/wiki/Standard_hydrogen_electrode). All missing elements in this table are either not metals or have a negative standard potential.

Arsenic, antimony and tellurium are considered to be [metalloids](https://en.wikipedia.org/wiki/Metalloid) and thus cannot be noble metals. Also, chemists and metallurgists consider copper and bismuth to not be noble metals because they easily oxidize due to the reaction O  
2 + 2 H  
2O + 4e− ⇄ 4 OH−  
(aq) + 0.40 V which is possible in moist air.

The film of silver is due to its high sensitivity to [hydrogen sulfide](https://en.wikipedia.org/wiki/Hydrogen_sulfide). Chemically, [patina](https://en.wikipedia.org/wiki/Patina) is caused by an attack of oxygen in wet air and by CO  
2 afterward.[[9]](https://en.wikipedia.org/wiki/Noble_metal#cite_note-HW2001-9) On the other hand, rhenium-coated mirrors are said to be very durable,[[9]](https://en.wikipedia.org/wiki/Noble_metal#cite_note-HW2001-9) although rhenium and technetium are said to tarnish slowly in moist atmosphere.[[14]](https://en.wikipedia.org/wiki/Noble_metal#cite_note-14)

The [superheavy elements](https://en.wikipedia.org/wiki/Superheavy_element" \o "Superheavy element) from [hassium](https://en.wikipedia.org/wiki/Hassium) to [livermorium](https://en.wikipedia.org/wiki/Livermorium) inclusive are expected to be "partially very noble metals"; chemical investigations of hassium has established that it behaves like its lighter congener osmium, and preliminary investigations of [nihonium](https://en.wikipedia.org/wiki/Nihonium" \o "Nihonium) and [flerovium](https://en.wikipedia.org/wiki/Flerovium) have suggested but not definitively established noble behavior.[[15]](https://en.wikipedia.org/wiki/Noble_metal#cite_note-15) [Copernicium](https://en.wikipedia.org/wiki/Copernicium)'s behaviour seems to partly resemble both its lighter congener mercury and the noble gas [radon](https://en.wikipedia.org/wiki/Radon).[[16]](https://en.wikipedia.org/wiki/Noble_metal#cite_note-CRNL-16)

See also[[edit](https://en.wikipedia.org/w/index.php?title=Noble_metal&action=edit&section=4)]

* [Minor metals](https://en.wikipedia.org/wiki/Minor_metals)

References[[edit](https://en.wikipedia.org/w/index.php?title=Noble_metal&action=edit&section=5)]

* *Brooks, Robert R., ed. (1992).*[*Noble Metals and Biological Systems: Their Role in Medicine, Mineral Exploration, and the Environment*](https://books.google.com/books?id=J4OkqlEJgl0C)*. Boca Raton, Fla.: CRC Press.*[*ISBN*](https://en.wikipedia.org/wiki/ISBN_(identifier))[*9780849361647*](https://en.wikipedia.org/wiki/Special:BookSources/9780849361647)*.*[*OCLC*](https://en.wikipedia.org/wiki/OCLC_(identifier))[*24379749*](https://www.worldcat.org/oclc/24379749)*.*

**Notes**

* 1. [**^**](https://en.wikipedia.org/wiki/Noble_metal#cite_ref-1) A. Holleman, N. Wiberg, "Lehrbuch der Anorganischen Chemie", de Gruyter, 1985, 33. edition, p. 1486
  2. [**^**](https://en.wikipedia.org/wiki/Noble_metal#cite_ref-2) [*"Edelmetall"*](http://www.uni-protokolle.de/Lexikon/Edelmetall.html)*. www.uni-protokolle.de. Retrieved April 6, 2018.*
  3. [**^**](https://en.wikipedia.org/wiki/Noble_metal#cite_ref-3) "Dictionary of Mining, Mineral, and Related Terms", Compiled by the American Geological Institute, 2nd edition, 1997
  4. [**^**](https://en.wikipedia.org/wiki/Noble_metal#cite_ref-4) Scoullos, M.J., Vonkeman, G.H., Thornton, I., Makuch, Z., "Mercury – Cadmium – Lead: Handbook for Sustainable Heavy Metals Policy and Regulation",Series: Environment & Policy, Vol. 31, Springer-Verlag, 2002
  5. [**^**](https://en.wikipedia.org/wiki/Noble_metal#cite_ref-5) The New Encyclopædia Britannica, 15th edition, Vol. VII, 1976
  6. [**^**](https://en.wikipedia.org/wiki/Noble_metal#cite_ref-6) [*"the definition of noble metal"*](http://dictionary.reference.com/browse/noble+metal)*. Dictionary.com. Retrieved April 6, 2018.*
  7. [**^**](https://en.wikipedia.org/wiki/Noble_metal#cite_ref-7) Everett Collier, "The Boatowner’s Guide to Corrosion", International Marine Publishing, 2001, p. 21
  8. [**^**](https://en.wikipedia.org/wiki/Noble_metal#cite_ref-WM2017_8-0) W. Xing, M. Lee, Geosys. Eng. 20, 216, 2017
  9. ^ [Jump up to:***a***](https://en.wikipedia.org/wiki/Noble_metal#cite_ref-HW2001_9-0) [***b***](https://en.wikipedia.org/wiki/Noble_metal#cite_ref-HW2001_9-1) [***c***](https://en.wikipedia.org/wiki/Noble_metal#cite_ref-HW2001_9-2) A. Holleman, N. Wiberg, "Inorganic Chemistry", Academic Press, 2001
  10. [**^**](https://en.wikipedia.org/wiki/Noble_metal#cite_ref-10) *Hüger, E.; Osuch, K. (2005). "Making a noble metal of Pd". EPL.****71****(2): 276.*[*Bibcode*](https://en.wikipedia.org/wiki/Bibcode_(identifier))*:*[*2005EL.....71..276H*](https://ui.adsabs.harvard.edu/abs/2005EL.....71..276H)*.*[*doi*](https://en.wikipedia.org/wiki/Doi_(identifier))*:*[*10.1209/epl/i2005-10075-5*](https://doi.org/10.1209%2Fepl%2Fi2005-10075-5)*.*
  11. [**^**](https://en.wikipedia.org/wiki/Noble_metal#cite_ref-11) S. Fuchs, T.Hahn, H.G. Lintz, "The oxidation of carbon monoxide by oxygen over platinum, palladium and rhodium catalysts from 10−10 to 1 bar", Chemical engineering and processing, 1994, V 33(5), pp. 363–369 [[1]](http://cat.inist.fr/?aModele=afficheN&cpsidt=3322977)
  12. [**^**](https://en.wikipedia.org/wiki/Noble_metal#cite_ref-12) G. Wulfsberg, "Inorganic Chemistry", University Science Books, 2000, pp. 247–249 ✦ Bratsch S. G., "Standard Electrode Potentials and Temperature Coefficients in Water at 298.15 K", *Journal of Physical Chemical Reference Data,* vol. 18, no. 1, 1989, pp. 1–21 ✦ B. Douglas, D. McDaniel, J. Alexander, "Concepts and Models of Inorganic Chemistry", John Wiley & Sons, 1994, p. E-3
  13. [**^**](https://en.wikipedia.org/wiki/Noble_metal#cite_ref-Haire_13-0) *Hoffman, Darleane C.; Lee, Diana M.; Pershina, Valeria (2006). "Transactinides and the future elements". In Morss; Edelstein, Norman M.; Fuger, Jean (eds.). The Chemistry of the Actinide and Transactinide Elements (3rd ed.). Dordrecht, The Netherlands:*[*Springer Science+Business Media*](https://en.wikipedia.org/wiki/Springer_Science%2BBusiness_Media)*.*[*ISBN*](https://en.wikipedia.org/wiki/ISBN_(identifier))[*1-4020-3555-1*](https://en.wikipedia.org/wiki/Special:BookSources/1-4020-3555-1)*.*
  14. [**^**](https://en.wikipedia.org/wiki/Noble_metal#cite_ref-14) R. D. Peack, "The Chemistry of Technetium and Rhenium", Elsevier, 1966
  15. [**^**](https://en.wikipedia.org/wiki/Noble_metal#cite_ref-15) *Nagame, Yuichiro; Kratz, Jens Volker; Matthias, Schädel (December 2015).*[*"Chemical studies of elements with Z ≥ 104 in liquid phase"*](https://jopss.jaea.go.jp/search/servlet/search?5050598)*. Nuclear Physics A.****944****: 614–639.*[*Bibcode*](https://en.wikipedia.org/wiki/Bibcode_(identifier))*:*[*2015NuPhA.944..614N*](https://ui.adsabs.harvard.edu/abs/2015NuPhA.944..614N)*.*[*doi*](https://en.wikipedia.org/wiki/Doi_(identifier))*:*[*10.1016/j.nuclphysa.2015.07.013*](https://doi.org/10.1016%2Fj.nuclphysa.2015.07.013)*.*
  16. [**^**](https://en.wikipedia.org/wiki/Noble_metal#cite_ref-CRNL_16-0) *Mewes, J.-M.; Smits, O. R.; Kresse, G.; Schwerdtfeger, P. (2019).*[*"Copernicium is a Relativistic Noble Liquid"*](https://www.researchgate.net/publication/336389017)*. Angewandte Chemie International Edition.*[*doi*](https://en.wikipedia.org/wiki/Doi_(identifier))*:*[*10.1002/anie.201906966*](https://doi.org/10.1002%2Fanie.201906966)*.*

External links[[edit](https://en.wikipedia.org/w/index.php?title=Noble_metal&action=edit&section=6)]

* [noble metal – chemistry](http://www.britannica.com/EBchecked/topic/416979/noble-metal) Encyclopædia Britannica, online edition
* To see which bands cross the Fermi level, the [Fermi surfaces](https://en.wikipedia.org/wiki/Fermi_surface) of almost all the metals can be found at the [Fermi Surface Database](http://www.phys.ufl.edu/fermisurface/)
* The following article might also clarify the correlation between *band structure* and the term *noble metal*: *Hüger, E.; Osuch, K. (2005). "Making a noble metal of Pd". EPL.****71****(2): 276.*[*Bibcode*](https://en.wikipedia.org/wiki/Bibcode_(identifier))*:*[*2005EL.....71..276H*](https://ui.adsabs.harvard.edu/abs/2005EL.....71..276H)*.*[*doi*](https://en.wikipedia.org/wiki/Doi_(identifier))*:*[*10.1209/epl/i2005-10075-5*](https://doi.org/10.1209%2Fepl%2Fi2005-10075-5)*.*

|  |  |
| --- | --- |
| hide   * [v](https://en.wikipedia.org/wiki/Template:Navbox_periodic_table) * [t](https://en.wikipedia.org/wiki/Template_talk:Navbox_periodic_table) * [e](https://en.wikipedia.org/w/index.php?title=Template:Navbox_periodic_table&action=edit)   [**Periodic table**](https://en.wikipedia.org/wiki/Periodic_table) | |
| **Periodic table forms** | |  |  | | --- | --- | | **Standard** | * [18-column](https://en.wikipedia.org/wiki/Periodic_table#Overview) * [32-column](https://en.wikipedia.org/wiki/Periodic_table#The_long-_or_32-column_table) | | **Alternative** | * [Alternatives](https://en.wikipedia.org/wiki/Alternative_periodic_tables) * [Janet's left step table](https://en.wikipedia.org/wiki/Alternative_periodic_tables#Left-step_periodic_table_(Janet,_1928)) | | **Extended** | * [Extension beyond the 7th period](https://en.wikipedia.org/wiki/Extended_periodic_table)   + [Aufbau](https://en.wikipedia.org/wiki/Extended_periodic_table#Aufbau_model)   + [Fricke](https://en.wikipedia.org/wiki/Fricke_model)   + [Pyykkö](https://en.wikipedia.org/wiki/Pyykk%C3%B6_model) | |
| [**Sets of elements**](https://en.wikipedia.org/wiki/Names_for_sets_of_chemical_elements) | |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | | **By periodic table structure** | |  |  | | --- | --- | | [**Groups**](https://en.wikipedia.org/wiki/Group_(periodic_table)) | * [1 (Alkali metals)](https://en.wikipedia.org/wiki/Alkali_metal) * [2 (Alkaline earth metals)](https://en.wikipedia.org/wiki/Alkaline_earth_metal) * [3](https://en.wikipedia.org/wiki/Group_3_element) * [4](https://en.wikipedia.org/wiki/Group_4_element) * [5](https://en.wikipedia.org/wiki/Group_5_element) * [6](https://en.wikipedia.org/wiki/Group_6_element) * [7](https://en.wikipedia.org/wiki/Group_7_element) * [8](https://en.wikipedia.org/wiki/Group_8_element) * [9](https://en.wikipedia.org/wiki/Group_9_element) * [10](https://en.wikipedia.org/wiki/Group_10_element) * [11](https://en.wikipedia.org/wiki/Group_11_element) * [12](https://en.wikipedia.org/wiki/Group_12_element) * [13](https://en.wikipedia.org/wiki/Boron_group) * [14](https://en.wikipedia.org/wiki/Carbon_group) * [15 (Pnictogens)](https://en.wikipedia.org/wiki/Pnictogen) * [16 (Chalcogens)](https://en.wikipedia.org/wiki/Chalcogen) * [17 (Halogens)](https://en.wikipedia.org/wiki/Halogen) * [18 (Noble gases)](https://en.wikipedia.org/wiki/Noble_gas) | | [**Periods**](https://en.wikipedia.org/wiki/Period_(periodic_table)) | * [1](https://en.wikipedia.org/wiki/Period_1_element) * [2](https://en.wikipedia.org/wiki/Period_2_element) * [3](https://en.wikipedia.org/wiki/Period_3_element) * [4](https://en.wikipedia.org/wiki/Period_4_element) * [5](https://en.wikipedia.org/wiki/Period_5_element) * [6](https://en.wikipedia.org/wiki/Period_6_element) * [7](https://en.wikipedia.org/wiki/Period_7_element) * [8+](https://en.wikipedia.org/wiki/Extended_periodic_table)   + [Aufbau](https://en.wikipedia.org/wiki/Extended_periodic_table#Aufbau_model)   + [Fricke](https://en.wikipedia.org/wiki/Fricke_model)   + [Pyykkö](https://en.wikipedia.org/wiki/Pyykk%C3%B6_model) | | [**Blocks**](https://en.wikipedia.org/wiki/Block_(periodic_table)) | * [s-block](https://en.wikipedia.org/wiki/S-block) * [p-block](https://en.wikipedia.org/wiki/P-block) * [d-block](https://en.wikipedia.org/wiki/D-block) * [f-block](https://en.wikipedia.org/wiki/F-block) * [g-block](https://en.wikipedia.org/wiki/G-block) * [Aufbau principle](https://en.wikipedia.org/wiki/Aufbau_principle) | | | **By**[**metallicity**](https://en.wikipedia.org/wiki/Properties_of_metals,_metalloids_and_nonmetals) | |  |  | | --- | --- | | [**Metals**](https://en.wikipedia.org/wiki/Metal) | * [Alkali metals](https://en.wikipedia.org/wiki/Alkali_metal) * [Alkaline earth metals](https://en.wikipedia.org/wiki/Alkaline_earth_metal) * [Lanthanides](https://en.wikipedia.org/wiki/Lanthanide) * [Actinides](https://en.wikipedia.org/wiki/Actinide) * [Transition metals](https://en.wikipedia.org/wiki/Transition_metal) * [Post-transition metals](https://en.wikipedia.org/wiki/Post-transition_metal) | | [**Metalloids**](https://en.wikipedia.org/wiki/Metalloid) | * [Lists of metalloids by source](https://en.wikipedia.org/wiki/List_of_metalloid_lists) * [Dividing line](https://en.wikipedia.org/wiki/Dividing_line_between_metals_and_nonmetals) | | [**Nonmetals**](https://en.wikipedia.org/wiki/Nonmetal) | * [Reactive nonmetals](https://en.wikipedia.org/wiki/Reactive_nonmetal) * [Noble gases](https://en.wikipedia.org/wiki/Noble_gas) | | | **Other sets** | * [Platinum-group metals (PGM)](https://en.wikipedia.org/wiki/Platinum_group) * [Rare-earth elements](https://en.wikipedia.org/wiki/Rare-earth_element) * [Refractory metals](https://en.wikipedia.org/wiki/Refractory_metals) * [Precious metals](https://en.wikipedia.org/wiki/Precious_metal) * [Coinage metals](https://en.wikipedia.org/wiki/Coinage_metals) * Noble metal * [Heavy metals](https://en.wikipedia.org/wiki/Heavy_metals) * [Native metals](https://en.wikipedia.org/wiki/Native_metal) * [Transuranium elements](https://en.wikipedia.org/wiki/Transuranium_element) * [Superheavy elements](https://en.wikipedia.org/wiki/Superheavy_element) * [Major actinides](https://en.wikipedia.org/wiki/Major_actinide) * [Minor actinides](https://en.wikipedia.org/wiki/Minor_actinide) | |
| [**Elements**](https://en.wikipedia.org/wiki/Chemical_element) | |  |  | | --- | --- | | [**Lists**](https://en.wikipedia.org/wiki/List_of_chemical_elements) | * By: [Abundance](https://en.wikipedia.org/wiki/Abundance_of_the_chemical_elements) ([in humans](https://en.wikipedia.org/wiki/Composition_of_the_human_body)) * [Atomic properties](https://en.wikipedia.org/wiki/List_of_elements_by_atomic_properties) * [Nuclear stability](https://en.wikipedia.org/wiki/List_of_elements_by_stability_of_isotopes) * [Production](https://en.wikipedia.org/wiki/List_of_world_production_chemical_elements) * [Symbol](https://en.wikipedia.org/wiki/Chemical_symbol) | | [**Properties**](https://en.wikipedia.org/wiki/Chemical_element#Properties) | * [Crystal structure](https://en.wikipedia.org/wiki/Periodic_table_(crystal_structure)) * [Electron configuration](https://en.wikipedia.org/wiki/Periodic_table_(electron_configurations)) * [Electronegativity](https://en.wikipedia.org/wiki/Electronegativity) * [Goldschmidt classification](https://en.wikipedia.org/wiki/Goldschmidt_classification) * [Term symbol](https://en.wikipedia.org/wiki/Term_symbol) | | **Data pages** | * [Abundance](https://en.wikipedia.org/wiki/Abundances_of_the_elements_(data_page)) * [Atomic radius](https://en.wikipedia.org/wiki/Atomic_radii_of_the_elements_(data_page)) * [Boiling point](https://en.wikipedia.org/wiki/Boiling_points_of_the_elements_(data_page)) * [Critical point](https://en.wikipedia.org/wiki/Critical_points_of_the_elements_(data_page)) * [Density](https://en.wikipedia.org/wiki/Densities_of_the_elements_(data_page)) * [Elasticity](https://en.wikipedia.org/wiki/Elastic_properties_of_the_elements_(data_page)) * [Electrical resistivity](https://en.wikipedia.org/wiki/Electrical_resistivities_of_the_elements_(data_page)) * [Electron affinity](https://en.wikipedia.org/wiki/Electron_affinity_(data_page)) * [Electron configuration](https://en.wikipedia.org/wiki/Electron_configurations_of_the_elements_(data_page)) * [Electronegativity](https://en.wikipedia.org/wiki/Electronegativities_of_the_elements_(data_page)) * [Hardness](https://en.wikipedia.org/wiki/Hardnesses_of_the_elements_(data_page)) * [Heat capacity](https://en.wikipedia.org/wiki/Heat_capacities_of_the_elements_(data_page)) * [Heat of fusion](https://en.wikipedia.org/wiki/Heats_of_fusion_of_the_elements_(data_page)) * [Heat of vaporization](https://en.wikipedia.org/wiki/Heats_of_vaporization_of_the_elements_(data_page)) * [Ionization energy](https://en.wikipedia.org/wiki/Ionization_energies_of_the_elements_(data_page)) * [Melting point](https://en.wikipedia.org/wiki/Melting_points_of_the_elements_(data_page)) * [Oxidation state](https://en.wikipedia.org/wiki/List_of_oxidation_states_of_the_elements) * [Speed of sound](https://en.wikipedia.org/wiki/Speeds_of_sound_of_the_elements_(data_page)) * [Thermal conductivity](https://en.wikipedia.org/wiki/Thermal_conductivities_of_the_elements_(data_page)) * [Thermal expansion coefficient](https://en.wikipedia.org/wiki/Thermal_expansion_coefficients_of_the_elements_(data_page)) * [Vapor pressure](https://en.wikipedia.org/wiki/Vapor_pressures_of_the_elements_(data_page)) | |
| [**History**](https://en.wikipedia.org/wiki/History_of_the_periodic_table) | * [Element discoveries](https://en.wikipedia.org/wiki/Timeline_of_chemical_element_discoveries)   + [Mendeleev's predictions](https://en.wikipedia.org/wiki/Mendeleev%27s_predicted_elements) * [Naming](https://en.wikipedia.org/wiki/Naming_of_chemical_elements)   + [etymology](https://en.wikipedia.org/wiki/List_of_chemical_element_name_etymologies)   + [controversies](https://en.wikipedia.org/wiki/List_of_chemical_elements_naming_controversies)   + [for places](https://en.wikipedia.org/wiki/List_of_places_used_in_the_names_of_chemical_elements)   + [for people](https://en.wikipedia.org/wiki/List_of_people_whose_names_are_used_in_chemical_element_names)   + [in East Asia](https://en.wikipedia.org/wiki/Chemical_elements_in_East_Asian_languages) |
| **See also** | * [IUPAC](https://en.wikipedia.org/wiki/International_Union_of_Pure_and_Applied_Chemistry)   + [nomenclature](https://en.wikipedia.org/wiki/Chemical_nomenclature)   + [systematic element name](https://en.wikipedia.org/wiki/Systematic_element_name) * [Trivial name](https://en.wikipedia.org/wiki/Trivial_name) * [Dmitri Mendeleev](https://en.wikipedia.org/wiki/Dmitri_Mendeleev) |
| * **Wikipedia book**[**Book**](https://en.wikipedia.org/wiki/Book:Periodic_table) * **Category**[**Category**](https://en.wikipedia.org/wiki/Category:Periodic_table) | |

[Categories](https://en.wikipedia.org/wiki/Help:Category):

* [Chemical nomenclature](https://en.wikipedia.org/wiki/Category:Chemical_nomenclature)
* [Metallurgy](https://en.wikipedia.org/wiki/Category:Metallurgy)
* [Noble metals](https://en.wikipedia.org/wiki/Category:Noble_metals)