Noble metal

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|  |
| --- |
| **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_%28element%29) (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.



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)



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* [4See also](https://en.wikipedia.org/wiki/Noble_metal#See_also)
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* [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 + H2O | 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_%28element%29) | 80 | 12 | 6 | Hg2+2 + 2 e−→ 2 Hg | 0.7925 V | [Xe]4f145d106s2 |
| [Selenium](https://en.wikipedia.org/wiki/Selenium) | 34 | 16 | 4 | H2SeO3 + 4 H+ + 4 e− → Se + 3 H2O | 0.739 V | [Ar]3d104s24p4 |
| [**Iridium**](https://en.wikipedia.org/wiki/Iridium) | 77 | 9 | 6 | IrO2 + 4 H+ + 4 e− → Ir + 2 H2O | 0.73 V | [Xe]4f145d76s2 |
| [**Osmium**](https://en.wikipedia.org/wiki/Osmium) | 76 | 8 | 6 | OsO2 + 4 H+ + 4 e− → Os + 2 H2O | 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 | TeO2 + 4 H+ + 4 e− → Te + 2 H2O | 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 | ReO2 + 4 H+ + 4 e− → Re + 2 H2O | 0.276 V | [Xe]4f145d56s2 |
| [Technetium](https://en.wikipedia.org/wiki/Technetium) | 43 | 7 | 5 | TcO2 + 4 H+ + 4 e− → Tc + 2 H2O | 0.272 V | [Kr]4d55s2 |
| [Arsenic](https://en.wikipedia.org/wiki/Arsenic) | 33 | 15 | 4 | As4O6 + 12 H+ + 12 e− → 4 As + 6 H2O | 0.24 V | [Ar]3d104s24p3 |
| [Antimony](https://en.wikipedia.org/wiki/Antimony) | 51 | 15 | 5 | Sb2O3 + 6 H+ + 6 e− → 2 Sb + 3 H2O | 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%22%20%5Co%20%22Pourbaix%20diagram) 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%22%20%5Co%20%22Superheavy%20element) 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%22%20%5Co%20%22Nihonium) 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)]

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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_%28identifier%29)*:*[*2005EL.....71..276H*](https://ui.adsabs.harvard.edu/abs/2005EL.....71..276H)*.*[*doi*](https://en.wikipedia.org/wiki/Doi_%28identifier%29)*:*[*10.1209/epl/i2005-10075-5*](https://doi.org/10.1209/epl/i2005-10075-5)*.*

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| hide* [v](https://en.wikipedia.org/wiki/Template%3ANavbox_periodic_table)
* [t](https://en.wikipedia.org/wiki/Template_talk%3ANavbox_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)
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