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**Cobalt**

From Wikipedia, the free encyclopedia

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

This article is about the chemical element. For other uses, see [Cobalt (disambiguation)](https://en.wikipedia.org/wiki/Cobalt_(disambiguation)).

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| --- | --- |
| Cobalt,  27Co | |
| [cobalt chips](https://en.wikipedia.org/wiki/File:Kobalt_electrolytic_and_1cm3_cube.jpg) | |
| **General properties** | |
| **Pronunciation** | [/ˈkoʊbɒlt/](https://en.wikipedia.org/wiki/Help:IPA/English) ([About this sound](https://en.wikipedia.org/wiki/File:En-us-cobalt.ogg)[listen](https://upload.wikimedia.org/wikipedia/commons/e/e5/En-us-cobalt.ogg))[[1]](https://en.wikipedia.org/wiki/Cobalt#cite_note-1) |
| **Appearance** | hard lustrous bluish gray metal |
| [**Standard atomic weight**](https://en.wikipedia.org/wiki/Standard_atomic_weight) **(*A*r, standard)** | 58.933194(3)[[2]](https://en.wikipedia.org/wiki/Cobalt#cite_note-CIAAW2016-2) |
| **Cobalt in the** [**periodic table**](https://en.wikipedia.org/wiki/Periodic_table) | |
| |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 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[Neon](https://en.wikipedia.org/wiki/Neon) | | [Sodium](https://en.wikipedia.org/wiki/Sodium) | [Magnesium](https://en.wikipedia.org/wiki/Magnesium) |  | | | | | | | | | | | | | | | | | | | | | | | | [Aluminium](https://en.wikipedia.org/wiki/Aluminium) | [Silicon](https://en.wikipedia.org/wiki/Silicon) | [Phosphorus](https://en.wikipedia.org/wiki/Phosphorus) | [Sulfur](https://en.wikipedia.org/wiki/Sulfur) | [Chlorine](https://en.wikipedia.org/wiki/Chlorine) | [Argon](https://en.wikipedia.org/wiki/Argon) | | [Potassium](https://en.wikipedia.org/wiki/Potassium) | [Calcium](https://en.wikipedia.org/wiki/Calcium) | [Scandium](https://en.wikipedia.org/wiki/Scandium) |  | | | | | | | | | | | | | | [Titanium](https://en.wikipedia.org/wiki/Titanium) | [Vanadium](https://en.wikipedia.org/wiki/Vanadium) | [Chromium](https://en.wikipedia.org/wiki/Chromium) | [Manganese](https://en.wikipedia.org/wiki/Manganese) | [Iron](https://en.wikipedia.org/wiki/Iron) | Cobalt | [Nickel](https://en.wikipedia.org/wiki/Nickel) | [Copper](https://en.wikipedia.org/wiki/Copper) | [Zinc](https://en.wikipedia.org/wiki/Zinc) | [Gallium](https://en.wikipedia.org/wiki/Gallium) | [Germanium](https://en.wikipedia.org/wiki/Germanium) | [Arsenic](https://en.wikipedia.org/wiki/Arsenic) | [Selenium](https://en.wikipedia.org/wiki/Selenium) | [Bromine](https://en.wikipedia.org/wiki/Bromine) | [Krypton](https://en.wikipedia.org/wiki/Krypton) | | [Rubidium](https://en.wikipedia.org/wiki/Rubidium) | [Strontium](https://en.wikipedia.org/wiki/Strontium) | [Yttrium](https://en.wikipedia.org/wiki/Yttrium) |  |  | | | | | | | | | | | | | [Zirconium](https://en.wikipedia.org/wiki/Zirconium) | [Niobium](https://en.wikipedia.org/wiki/Niobium) | [Molybdenum](https://en.wikipedia.org/wiki/Molybdenum) | [Technetium](https://en.wikipedia.org/wiki/Technetium) | [Ruthenium](https://en.wikipedia.org/wiki/Ruthenium) | [Rhodium](https://en.wikipedia.org/wiki/Rhodium) | [Palladium](https://en.wikipedia.org/wiki/Palladium) | [Silver](https://en.wikipedia.org/wiki/Silver) | [Cadmium](https://en.wikipedia.org/wiki/Cadmium) | [Indium](https://en.wikipedia.org/wiki/Indium) | [Tin](https://en.wikipedia.org/wiki/Tin) | [Antimony](https://en.wikipedia.org/wiki/Antimony) | [Tellurium](https://en.wikipedia.org/wiki/Tellurium) | [Iodine](https://en.wikipedia.org/wiki/Iodine) | [Xenon](https://en.wikipedia.org/wiki/Xenon) | | [Caesium](https://en.wikipedia.org/wiki/Caesium) | [Barium](https://en.wikipedia.org/wiki/Barium) | [Lanthanum](https://en.wikipedia.org/wiki/Lanthanum) | [Cerium](https://en.wikipedia.org/wiki/Cerium) | [Praseodymium](https://en.wikipedia.org/wiki/Praseodymium) | [Neodymium](https://en.wikipedia.org/wiki/Neodymium) | [Promethium](https://en.wikipedia.org/wiki/Promethium) | [Samarium](https://en.wikipedia.org/wiki/Samarium) | [Europium](https://en.wikipedia.org/wiki/Europium) | [Gadolinium](https://en.wikipedia.org/wiki/Gadolinium) | [Terbium](https://en.wikipedia.org/wiki/Terbium) | [Dysprosium](https://en.wikipedia.org/wiki/Dysprosium) | [Holmium](https://en.wikipedia.org/wiki/Holmium) | [Erbium](https://en.wikipedia.org/wiki/Erbium) | [Thulium](https://en.wikipedia.org/wiki/Thulium) | [Ytterbium](https://en.wikipedia.org/wiki/Ytterbium) | [Lutetium](https://en.wikipedia.org/wiki/Lutetium) | [Hafnium](https://en.wikipedia.org/wiki/Hafnium) | [Tantalum](https://en.wikipedia.org/wiki/Tantalum) | [Tungsten](https://en.wikipedia.org/wiki/Tungsten) | [Rhenium](https://en.wikipedia.org/wiki/Rhenium) | [Osmium](https://en.wikipedia.org/wiki/Osmium) | [Iridium](https://en.wikipedia.org/wiki/Iridium) | [Platinum](https://en.wikipedia.org/wiki/Platinum) | [Gold](https://en.wikipedia.org/wiki/Gold) | [Mercury (element)](https://en.wikipedia.org/wiki/Mercury_(element)) | [Thallium](https://en.wikipedia.org/wiki/Thallium) | [Lead](https://en.wikipedia.org/wiki/Lead) | [Bismuth](https://en.wikipedia.org/wiki/Bismuth) | [Polonium](https://en.wikipedia.org/wiki/Polonium) | [Astatine](https://en.wikipedia.org/wiki/Astatine) | [Radon](https://en.wikipedia.org/wiki/Radon) | | [Francium](https://en.wikipedia.org/wiki/Francium) | [Radium](https://en.wikipedia.org/wiki/Radium) | [Actinium](https://en.wikipedia.org/wiki/Actinium) | [Thorium](https://en.wikipedia.org/wiki/Thorium) | [Protactinium](https://en.wikipedia.org/wiki/Protactinium) | [Uranium](https://en.wikipedia.org/wiki/Uranium) | [Neptunium](https://en.wikipedia.org/wiki/Neptunium) | [Plutonium](https://en.wikipedia.org/wiki/Plutonium) | [Americium](https://en.wikipedia.org/wiki/Americium) | [Curium](https://en.wikipedia.org/wiki/Curium) | [Berkelium](https://en.wikipedia.org/wiki/Berkelium) | [Californium](https://en.wikipedia.org/wiki/Californium) | [Einsteinium](https://en.wikipedia.org/wiki/Einsteinium) | [Fermium](https://en.wikipedia.org/wiki/Fermium) | [Mendelevium](https://en.wikipedia.org/wiki/Mendelevium) | [Nobelium](https://en.wikipedia.org/wiki/Nobelium) | [Lawrencium](https://en.wikipedia.org/wiki/Lawrencium) | [Rutherfordium](https://en.wikipedia.org/wiki/Rutherfordium) | [Dubnium](https://en.wikipedia.org/wiki/Dubnium) | [Seaborgium](https://en.wikipedia.org/wiki/Seaborgium) | [Bohrium](https://en.wikipedia.org/wiki/Bohrium) | [Hassium](https://en.wikipedia.org/wiki/Hassium) | [Meitnerium](https://en.wikipedia.org/wiki/Meitnerium) | [Darmstadtium](https://en.wikipedia.org/wiki/Darmstadtium) | [Roentgenium](https://en.wikipedia.org/wiki/Roentgenium) | [Copernicium](https://en.wikipedia.org/wiki/Copernicium) | [Nihonium](https://en.wikipedia.org/wiki/Nihonium) | [Flerovium](https://en.wikipedia.org/wiki/Flerovium) | [Moscovium](https://en.wikipedia.org/wiki/Moscovium) | [Livermorium](https://en.wikipedia.org/wiki/Livermorium) | [Tennessine](https://en.wikipedia.org/wiki/Tennessine) | [Oganesson](https://en.wikipedia.org/wiki/Oganesson) | | – ↑ **Co** ↓ [Rh](https://en.wikipedia.org/wiki/Rhodium) | | [iron](https://en.wikipedia.org/wiki/Iron) ← **cobalt** → [nickel](https://en.wikipedia.org/wiki/Nickel) | | | | |
| [**Atomic number**](https://en.wikipedia.org/wiki/Atomic_number)(*Z*) | 27 |
| [**Group**](https://en.wikipedia.org/wiki/Group_(periodic_table)) | [group 9](https://en.wikipedia.org/wiki/Group_9_element) |
| [**Period**](https://en.wikipedia.org/wiki/Period_(periodic_table)) | [period 4](https://en.wikipedia.org/wiki/Period_(periodic_table)#Period_4) |
| [**Block**](https://en.wikipedia.org/wiki/Block_(periodic_table)) | [d-block](https://en.wikipedia.org/wiki/D-block) |
| [**Element category**](https://en.wikipedia.org/wiki/Names_for_sets_of_chemical_elements#Category) | [transition metal](https://en.wikipedia.org/wiki/Transition_metal) |
| [**Electron configuration**](https://en.wikipedia.org/wiki/Electron_configuration) | [[Ar](https://en.wikipedia.org/wiki/Argon)] 3d7 4s2 |
| Electrons per shell | 2, 8, 15, 2 |
| **Physical properties** | |
| [**Phase**](https://en.wikipedia.org/wiki/Phase_(matter)) **at**[**STP**](https://en.wikipedia.org/wiki/Standard_conditions_for_temperature_and_pressure) | [solid](https://en.wikipedia.org/wiki/Solid) |
| [**Melting point**](https://en.wikipedia.org/wiki/Melting_point) | 1768 [K](https://en.wikipedia.org/wiki/Kelvin) ​(1495 °C, ​2723 °F) |
| [**Boiling point**](https://en.wikipedia.org/wiki/Boiling_point) | 3200 K ​(2927 °C, ​5301 °F) |
| [**Density**](https://en.wikipedia.org/wiki/Density)(near r.t.) | 8.90 g/cm3 |
| when liquid (at m.p.) | 8.86 g/cm3 |
| [**Heat of fusion**](https://en.wikipedia.org/wiki/Enthalpy_of_fusion) | 16.06 [kJ/mol](https://en.wikipedia.org/wiki/Kilojoule_per_mole) |
| [**Heat of vaporization**](https://en.wikipedia.org/wiki/Enthalpy_of_vaporization) | 377 kJ/mol |
| [**Molar heat capacity**](https://en.wikipedia.org/wiki/Molar_heat_capacity) | 24.81 J/(mol·K) |
| [**Vapor pressure**](https://en.wikipedia.org/wiki/Vapor_pressure)   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | ***P***(Pa) | **1** | **10** | **100** | **1 k** | **10 k** | **100 k** | | **at *T***(K) | 1790 | 1960 | 2165 | 2423 | 2755 | 3198 | | |
| **Atomic properties** | |
| [**Oxidation states**](https://en.wikipedia.org/wiki/Oxidation_state) | −3, −1, +1, **+2**, **+3**, +4, +5[[3]](https://en.wikipedia.org/wiki/Cobalt#cite_note-greenwood-3) (an [amphoteric](https://en.wikipedia.org/wiki/Amphoterism) oxide) |
| [**Electronegativity**](https://en.wikipedia.org/wiki/Electronegativity) | Pauling scale: 1.88 |
| [**Ionization energies**](https://en.wikipedia.org/wiki/Ionization_energy) | * 1st: 760.4 kJ/mol * 2nd: 1648 kJ/mol * 3rd: 3232 kJ/mol * ([more](https://en.wikipedia.org/wiki/Molar_ionization_energies_of_the_elements#cobalt)) |
| [**Atomic radius**](https://en.wikipedia.org/wiki/Atomic_radius) | empirical: 125 [pm](https://en.wikipedia.org/wiki/Picometre) |
| [**Covalent radius**](https://en.wikipedia.org/wiki/Covalent_radius) | Low spin: 126±3 pm High spin: 150±7 pm |
| [Color lines in a spectral range](https://en.wikipedia.org/wiki/File:Cobalt_spectrum_visible.png)  [**Spectral lines**](https://en.wikipedia.org/wiki/Spectral_line) **of cobalt** | |
| **Other properties** | |
| [**Crystal structure**](https://en.wikipedia.org/wiki/Crystal_structure) | ​[hexagonal close-packed](https://en.wikipedia.org/wiki/Close-packing_of_equal_spheres) (hcp)  [Hexagonal close packed crystal structure for cobalt](https://en.wikipedia.org/wiki/File:Hexagonal_close_packed.svg) |
| [**Speed of sound**](https://en.wikipedia.org/wiki/Speed_of_sound)thin rod | 4720 m/s (at 20 °C) |
| [**Thermal expansion**](https://en.wikipedia.org/wiki/Coefficient_of_thermal_expansion) | 13.0 µm/(m·K) (at 25 °C) |
| [**Thermal conductivity**](https://en.wikipedia.org/wiki/Thermal_conductivity) | 100 W/(m·K) |
| [**Electrical resistivity**](https://en.wikipedia.org/wiki/Electrical_resistivity_and_conductivity) | 62.4 nΩ·m (at 20 °C) |
| [**Magnetic ordering**](https://en.wikipedia.org/wiki/Magnetism) | [ferromagnetic](https://en.wikipedia.org/wiki/Ferromagnetism) |
| [**Young's modulus**](https://en.wikipedia.org/wiki/Young%27s_modulus) | 209 GPa |
| [**Shear modulus**](https://en.wikipedia.org/wiki/Shear_modulus) | 75 GPa |
| [**Bulk modulus**](https://en.wikipedia.org/wiki/Bulk_modulus) | 180 GPa |
| [**Poisson ratio**](https://en.wikipedia.org/wiki/Poisson%27s_ratio) | 0.31 |
| [**Mohs hardness**](https://en.wikipedia.org/wiki/Mohs_scale_of_mineral_hardness) | 5.0 |
| [**Vickers hardness**](https://en.wikipedia.org/wiki/Vickers_hardness_test) | 1043 MPa |
| [**Brinell hardness**](https://en.wikipedia.org/wiki/Brinell_hardness_test) | 470–3000 MPa |
| [**CAS Number**](https://en.wikipedia.org/wiki/CAS_Registry_Number) | 7440-48-4 |
| **History** | |
| [**Discovery**](https://en.wikipedia.org/wiki/Timeline_of_chemical_element_discoveries) **and first isolation** | [Georg Brandt](https://en.wikipedia.org/wiki/Georg_Brandt) (1735) |
| **Main** [**isotopes of cobalt**](https://en.wikipedia.org/wiki/Isotopes_of_cobalt) | |
| |  |  |  |  |  | | --- | --- | --- | --- | --- | | [**Iso­tope**](https://en.wikipedia.org/wiki/Isotope) | [**Abun­dance**](https://en.wikipedia.org/wiki/Natural_abundance) | [**Half-life**](https://en.wikipedia.org/wiki/Half-life) **(*t*1/2)** | [**Decay mode**](https://en.wikipedia.org/wiki/Radioactive_decay) | [**Pro­duct**](https://en.wikipedia.org/wiki/Decay_product) | | **56Co** | [syn](https://en.wikipedia.org/wiki/Synthetic_radioisotope) | 77.27 d | [ε](https://en.wikipedia.org/wiki/Electron_capture) | [56Fe](https://en.wikipedia.org/wiki/Iron-56) | | **57Co** | syn | 271.79 d | ε | [57Fe](https://en.wikipedia.org/wiki/Iron-57) | | **58Co** | syn | 70.86 d | ε | [58Fe](https://en.wikipedia.org/wiki/Iron-58) | | **59Co** | 100% | [stable](https://en.wikipedia.org/wiki/Stable_isotope) | | | | **60Co** | syn | 5.2714 y | [β−](https://en.wikipedia.org/wiki/Beta_decay), [γ](https://en.wikipedia.org/wiki/Gamma_decay) | [60Ni](https://en.wikipedia.org/wiki/Nickel-60) | | |
| * [view](https://en.wikipedia.org/wiki/Template:Infobox_cobalt) * [talk](https://en.wikipedia.org/wiki/Template_talk:Infobox_cobalt) * [edit](https://en.wikipedia.org/w/index.php?title=Template:Infobox_cobalt&action=edit)   | [references](https://en.wikipedia.org/wiki/List_of_data_references_for_chemical_elements) | |

**Cobalt** is a [chemical element](https://en.wikipedia.org/wiki/Chemical_element) with symbol **Co** and atomic number 27. Like nickel, cobalt is found in the Earth's crust only in chemically combined form, save for small deposits found in alloys of natural [meteoric iron](https://en.wikipedia.org/wiki/Meteoric_iron). The free element, produced by reductive [smelting](https://en.wikipedia.org/wiki/Smelting), is a hard, lustrous, silver-gray [metal](https://en.wikipedia.org/wiki/Metal).

Cobalt-based blue pigments ([cobalt blue](https://en.wikipedia.org/wiki/Cobalt_blue)) have been used since ancient times for jewelry and paints, and to impart a distinctive blue tint to glass, but the color was later thought by alchemists to be due to the known metal [bismuth](https://en.wikipedia.org/wiki/Bismuth). Miners had long used the name [*kobold*](https://en.wikipedia.org/wiki/Kobold) *ore* (German for *goblin ore*) for some of the blue-pigment producing [minerals](https://en.wikipedia.org/wiki/Minerals); they were so named because they were poor in known metals, and gave poisonous [arsenic](https://en.wikipedia.org/wiki/Arsenic)-containing fumes when smelted. In 1735, such ores were found to be reducible to a new metal (the first discovered since ancient times), and this was ultimately named for the *kobold*.

Today, some cobalt is produced specifically from one of a number of metallic-lustered ores, such as for example [cobaltite](https://en.wikipedia.org/wiki/Cobaltite) (Co[As](https://en.wikipedia.org/wiki/Arsenic)[S](https://en.wikipedia.org/wiki/Sulfur)). The element is however more usually produced as a by-product of [copper](https://en.wikipedia.org/wiki/Copper) and [nickel](https://en.wikipedia.org/wiki/Nickel) mining. [The copper belt](https://en.wikipedia.org/wiki/Copperbelt) in the [Democratic Republic of the Congo](https://en.wikipedia.org/wiki/Democratic_Republic_of_the_Congo) (DRC) and [Zambia](https://en.wikipedia.org/wiki/Zambia) yields most of the global cobalt production. The DRC alone accounted for more than 50% of world production in 2016 (123,000 tonnes), according to [Natural Resources Canada](https://en.wikipedia.org/wiki/Natural_Resources_Canada).[[4]](https://en.wikipedia.org/wiki/Cobalt#cite_note-4)

Cobalt is primarily used in the manufacture of [magnetic](https://en.wikipedia.org/wiki/Magnetism), wear-resistant and high-strength [alloys](https://en.wikipedia.org/wiki/Alloy). The compounds cobalt silicate and [cobalt(II) aluminate](https://en.wikipedia.org/wiki/Cobalt_blue) (CoAl2O4, cobalt blue) give a distinctive deep blue color to [glass](https://en.wikipedia.org/wiki/Glass), [ceramics](https://en.wikipedia.org/wiki/Ceramic), [inks](https://en.wikipedia.org/wiki/Ink), [paints](https://en.wikipedia.org/wiki/Paint) and [varnishes](https://en.wikipedia.org/wiki/Varnish). Cobalt occurs naturally as only one stable [isotope](https://en.wikipedia.org/wiki/Isotope), cobalt-59. [Cobalt-60](https://en.wikipedia.org/wiki/Cobalt-60) is a commercially important radioisotope, used as a [radioactive tracer](https://en.wikipedia.org/wiki/Radioactive_tracer) and for the production of high energy [gamma rays](https://en.wikipedia.org/wiki/Gamma_ray).

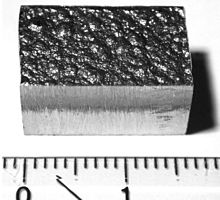
Cobalt is the active center of a group of [coenzymes](https://en.wikipedia.org/wiki/Coenzymes) called [cobalamins](https://en.wikipedia.org/wiki/Cobalamin). [vitamin B12](https://en.wikipedia.org/wiki/Vitamin_B12), the best-known example of the type, is an essential [vitamin](https://en.wikipedia.org/wiki/Vitamin) for all animals. Cobalt in inorganic form is also a [micronutrient](https://en.wikipedia.org/wiki/Micronutrient) for [bacteria](https://en.wikipedia.org/wiki/Bacteria), [algae](https://en.wikipedia.org/wiki/Algae), and [fungi](https://en.wikipedia.org/wiki/Fungi).



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**Characteristics**

[](https://en.wikipedia.org/wiki/File:Kobalt_13g.jpg)

A block of [electrolytically](https://en.wikipedia.org/wiki/Electrolysis) refined cobalt (99.9% purity) cut from a large plate

Cobalt is a [ferromagnetic](https://en.wikipedia.org/wiki/Ferromagnetism) metal with a [specific gravity](https://en.wikipedia.org/wiki/Specific_gravity) of 8.9. The [Curie temperature](https://en.wikipedia.org/wiki/Curie_temperature) is 1,115 °C (2,039 °F)[[5]](https://en.wikipedia.org/wiki/Cobalt#cite_note-5) and the magnetic moment is 1.6–1.7 [Bohr magnetons](https://en.wikipedia.org/wiki/Bohr_magneton) per [atom](https://en.wikipedia.org/wiki/Atom).[[6]](https://en.wikipedia.org/wiki/Cobalt#cite_note-6) Cobalt has a [relative permeability](https://en.wikipedia.org/wiki/Permeability_(electromagnetism)) two-thirds that of [iron](https://en.wikipedia.org/wiki/Iron).[[7]](https://en.wikipedia.org/wiki/Cobalt#cite_note-7) [Metallic](https://en.wikipedia.org/wiki/Metal) cobalt occurs as two [crystallographic structures](https://en.wikipedia.org/wiki/Crystallographic_structure): [hcp](https://en.wikipedia.org/wiki/Hexagonal_close_packed) and [fcc](https://en.wikipedia.org/wiki/Face-centered_cubic). The ideal transition temperature between the hcp and fcc structures is 450 °C (842 °F), but in practice the energy difference between them is so small that random intergrowth of the two is common.[[8]](https://en.wikipedia.org/wiki/Cobalt#cite_note-8)[[9]](https://en.wikipedia.org/wiki/Cobalt#cite_note-9)[[10]](https://en.wikipedia.org/wiki/Cobalt#cite_note-10)

Cobalt is a weakly reducing metal that is protected from oxidation by a [passivating](https://en.wikipedia.org/wiki/Passivation_(chemistry)) [oxide](https://en.wikipedia.org/wiki/Oxide) film. It is attacked by [halogens](https://en.wikipedia.org/wiki/Halogens) and [sulfur](https://en.wikipedia.org/wiki/Sulfur). Heating in [oxygen](https://en.wikipedia.org/wiki/Oxygen) produces [Co3O4](https://en.wikipedia.org/wiki/Cobalt(II,III)_oxide) which loses oxygen at 900 °C (1,650 °F) to give the [monoxide](https://en.wikipedia.org/wiki/Cobalt(II)_oxide) CoO.[[11]](https://en.wikipedia.org/wiki/Cobalt#cite_note-HollemanAF-11) The metal reacts with [fluorine](https://en.wikipedia.org/wiki/Fluorine) ([F2](https://en.wikipedia.org/wiki/Fluorine)) at 520 K to give [CoF3](https://en.wikipedia.org/wiki/Cobalt(III)_fluoride); with [chlorine](https://en.wikipedia.org/wiki/Chlorine) ([Cl2](https://en.wikipedia.org/wiki/Chlorine)), [bromine](https://en.wikipedia.org/wiki/Bromine) ([Br2](https://en.wikipedia.org/wiki/Bromine)) and [iodine](https://en.wikipedia.org/wiki/Iodine) ([I2](https://en.wikipedia.org/wiki/Iodine)), producing equivalent binary [halides](https://en.wikipedia.org/wiki/Halides). It does not react with [hydrogen gas](https://en.wikipedia.org/wiki/Hydrogen_gas) ([H2](https://en.wikipedia.org/wiki/Hydrogen)) or [nitrogen gas](https://en.wikipedia.org/wiki/Nitrogen_gas) ([N2](https://en.wikipedia.org/wiki/Nitrogen)) even when heated, but it does react with [boron](https://en.wikipedia.org/wiki/Boron), [carbon](https://en.wikipedia.org/wiki/Carbon), [phosphorus](https://en.wikipedia.org/wiki/Phosphorus), [arsenic](https://en.wikipedia.org/wiki/Arsenic) and sulfur.[[12]](https://en.wikipedia.org/wiki/Cobalt#cite_note-12) At ordinary temperatures, it reacts slowly with [mineral acids](https://en.wikipedia.org/wiki/Mineral_acids), and very slowly with moist, but not with dry, air.

**Compounds**

See also: [Category:Cobalt compounds](https://en.wikipedia.org/wiki/Category:Cobalt_compounds).

Common [oxidation states](https://en.wikipedia.org/wiki/Oxidation_states) of cobalt include +2 and +3, although compounds with oxidation states ranging from −3 to [+5](https://en.wikipedia.org/wiki/Percobaltate) are also known. A common oxidation state for simple compounds is +2 (cobalt(II)). These salts form the pink-colored [metal aquo complex](https://en.wikipedia.org/wiki/Metal_aquo_complex) [Co(H2O)6]2+ in water. Addition of chloride gives the intensely blue [CoCl  
4]2−  
.[[3]](https://en.wikipedia.org/wiki/Cobalt#cite_note-greenwood-3) In a borax bead [flame test](https://en.wikipedia.org/wiki/Flame_test), cobalt shows deep blue in both oxidizing and reducing flames.[[13]](https://en.wikipedia.org/wiki/Cobalt#cite_note-13)

**Oxygen and chalcogen compounds**

Several [oxides](https://en.wikipedia.org/wiki/Oxide) of cobalt are known. Green [cobalt(II) oxide](https://en.wikipedia.org/wiki/Cobalt(II)_oxide) (CoO) has [rocksalt](https://en.wikipedia.org/wiki/Cubic_crystal_system) structure. It is readily oxidized with water and oxygen to brown cobalt(III) hydroxide (Co(OH)3). At temperatures of 600–700 °C, CoO oxidizes to the blue [cobalt(II,III) oxide](https://en.wikipedia.org/wiki/Cobalt(II,III)_oxide) (Co3O4), which has a [spinel](https://en.wikipedia.org/wiki/Spinel) structure.[[3]](https://en.wikipedia.org/wiki/Cobalt#cite_note-greenwood-3) Black [cobalt(III) oxide](https://en.wikipedia.org/wiki/Cobalt(III)_oxide) (Co2O3) is also known.[[14]](https://en.wikipedia.org/wiki/Cobalt#cite_note-14) Cobalt oxides are [antiferromagnetic](https://en.wikipedia.org/wiki/Antiferromagnetic) at low [temperature](https://en.wikipedia.org/wiki/Temperature): CoO ([Néel temperature](https://en.wikipedia.org/wiki/N%C3%A9el_temperature) 291 K) and Co3O4 (Néel temperature: 40 K), which is analogous to [magnetite](https://en.wikipedia.org/wiki/Magnetite) (Fe3O4), with a mixture of +2 and +3 oxidation states.[[15]](https://en.wikipedia.org/wiki/Cobalt#cite_note-15)

The principal [chalcogenides](https://en.wikipedia.org/wiki/Chalcogen) of cobalt include the black [cobalt(II) sulfides](https://en.wikipedia.org/wiki/Cobalt(II)_sulfide), CoS2, which adopts a [pyrite](https://en.wikipedia.org/wiki/Pyrite)-like structure, and [cobalt(III) sulfide](https://en.wikipedia.org/wiki/Cobalt_sulfide) (Co2S3).

**Halides**

[](https://en.wikipedia.org/wiki/File:Cobalt(II)-chloride-hexahydrate-sample.jpg)

Cobalt(II) chloride hexahydrate

Four [dihalides](https://en.wiktionary.org/wiki/dihalide) of cobalt(II) are known: [cobalt(II) fluoride](https://en.wikipedia.org/wiki/Cobalt(II)_fluoride) (CoF2, pink), [cobalt(II) chloride](https://en.wikipedia.org/wiki/Cobalt(II)_chloride) (CoCl2, blue), [cobalt(II) bromide](https://en.wikipedia.org/wiki/Cobalt(II)_bromide) (CoBr2, green), [cobalt(II) iodide](https://en.wikipedia.org/wiki/Cobalt(II)_iodide) (CoI2, blue-black). These halides exist in anhydrous and hydrated forms. Whereas the anhydrous dichloride is blue, the hydrate is red.[[16]](https://en.wikipedia.org/wiki/Cobalt#cite_note-greenwood2-16)

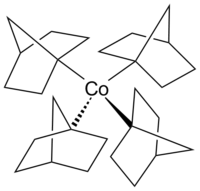
The reduction potential for the reaction Co3+  
+ e− → Co2+  
is +1.92 V, beyond that for [chlorine](https://en.wikipedia.org/wiki/Chlorine) to chloride, +1.36 V. Consequently, cobalt(III) and chloride would result in the cobalt(III) being reduced to cobalt(II). Because the reduction potential for fluorine to fluoride is so high, +2.87 V, [cobalt(III) fluoride](https://en.wikipedia.org/wiki/Cobalt(III)_fluoride) is one of the few simple stable cobalt(III) compounds. Cobalt(III) fluoride, which is used in some fluorination reactions, reacts vigorously with water.[[11]](https://en.wikipedia.org/wiki/Cobalt#cite_note-HollemanAF-11)

**Coordination compounds**

As for all metals, molecular compounds and polyatomic ions of cobalt are classified as [coordination complexes](https://en.wikipedia.org/wiki/Coordination_complex), that is, molecules or ions that contain cobalt linked to several [ligands](https://en.wikipedia.org/wiki/Ligand). The principles of [electronegativity](https://en.wikipedia.org/wiki/Electronegativity) and [hardness–softness](https://en.wikipedia.org/wiki/HSAB_theory) of a series of ligands can be used to explain the usual oxidation state of cobalt. For example, Co+3 complexes tend to have [ammine](https://en.wikipedia.org/wiki/Ammine) ligands. Because phosphorus is softer than nitrogen, phosphine ligands tend to feature the [softer](https://en.wikipedia.org/wiki/HSAB_theory) Co2+ and Co+, an example being tris(triphenylphosphine)cobalt(I) chloride ((P(C6H5)3)3CoCl). The more electronegative (and harder) oxide and fluoride can stabilize Co4+ and Co5+ derivatives, e.g. caesium hexafluorocobaltate (Cs2CoF6) and potassium [percobaltate](https://en.wikipedia.org/wiki/Percobaltate) (K3CoO4).[[11]](https://en.wikipedia.org/wiki/Cobalt#cite_note-HollemanAF-11)

[Alfred Werner](https://en.wikipedia.org/wiki/Alfred_Werner), a Nobel-prize winning pioneer in [coordination chemistry](https://en.wikipedia.org/wiki/Coordination_chemistry), worked with compounds of [empirical formula](https://en.wikipedia.org/wiki/Empirical_formula) [Co(NH3)6]Cl3. One of the isomers determined was [cobalt(III) hexammine chloride](https://en.wikipedia.org/wiki/Cobalt(III)_hexammine_chloride). This coordination complex, a typical Werner-type complex, consists of a central cobalt atom coordinated by six [ammine](https://en.wikipedia.org/wiki/Ammine) orthogonal ligands and three [chloride](https://en.wikipedia.org/wiki/Chloride) counteranions. Using [chelating](https://en.wikipedia.org/wiki/Chelation) [ethylenediamine](https://en.wikipedia.org/wiki/Ethylenediamine) ligands in place of ammonia gives [tris(ethylenediamine)cobalt(III) chloride](https://en.wikipedia.org/wiki/Tris(ethylenediamine)cobalt(III)_chloride) ([Co(en)3]Cl3), which was one of the first [coordination complexes](https://en.wikipedia.org/wiki/Coordination_complex) to be resolved into [optical isomers](https://en.wikipedia.org/wiki/Chirality_(chemistry)). The complex exists in the right- and left-handed forms of a "three-bladed propeller". This complex was first isolated by Werner as yellow-gold needle-like crystals.[[17]](https://en.wikipedia.org/wiki/Cobalt#cite_note-17)[[18]](https://en.wikipedia.org/wiki/Cobalt#cite_note-18)

**Organometallic compounds**

[](https://en.wikipedia.org/wiki/File:Tetrakis(1-norbornyl)cobalt(IV).png)

Structure of tetrakis(1-norbornyl)cobalt(IV)

Main article: [Organocobalt chemistry](https://en.wikipedia.org/wiki/Organocobalt_chemistry)

[Cobaltocene](https://en.wikipedia.org/wiki/Cobaltocene) is a [structural analog](https://en.wikipedia.org/wiki/Structural_analog) to [ferrocene](https://en.wikipedia.org/wiki/Ferrocene), with cobalt in place of iron. Cobaltocene is much more sensitive to [oxidation](https://en.wikipedia.org/wiki/Oxidation) than ferrocene.[[19]](https://en.wikipedia.org/wiki/Cobalt#cite_note-19) Cobalt carbonyl ([Co2(CO)8](https://en.wikipedia.org/wiki/Dicobalt_octacarbonyl)) is a [catalyst](https://en.wikipedia.org/wiki/Catalysis) in [carbonylation](https://en.wikipedia.org/wiki/Carbonylation) and [hydrosilylation](https://en.wikipedia.org/wiki/Hydrosilylation) reactions.[[20]](https://en.wikipedia.org/wiki/Cobalt#cite_note-20) Vitamin B12 (see [below](https://en.wikipedia.org/wiki/Bush_sickness)) is an organometallic compound found in nature and is the only [vitamin](https://en.wikipedia.org/wiki/Vitamin) that contains a metal atom.[[21]](https://en.wikipedia.org/wiki/Cobalt#cite_note-21) An example of an alkylcobalt complex in the otherwise uncommon +4 oxidation state of cobalt is the homoleptic complex [tetrakis(1-norbornyl)cobalt(IV)](https://en.wikipedia.org/w/index.php?title=Tetrakis(1-norbornyl)cobalt(IV)&action=edit&redlink=1) [[de](https://de.wikipedia.org/wiki/tetrakis(1-norbornyl)cobalt(IV))] (Co(1-norb)4), a transition metal-alkyl complex that is notable for its stability to [β-hydrogen elimination](https://en.wikipedia.org/wiki/Beta-Hydride_elimination).[[22]](https://en.wikipedia.org/wiki/Cobalt#cite_note-22) The cobalt(III) and cobalt(V) complexes [Li(THF)4]+[Co(1-norb)4]− and [Co(1-norb)4]+[BF4]− are also known.[[23]](https://en.wikipedia.org/wiki/Cobalt#cite_note-23)

**Isotopes**

Main article: [Isotopes of cobalt](https://en.wikipedia.org/wiki/Isotopes_of_cobalt)

59Co is the only stable cobalt [isotope](https://en.wikipedia.org/wiki/Isotope) and the only [isotope](https://en.wikipedia.org/wiki/Isotope) that exists naturally on Earth. Twenty-two [radioisotopes](https://en.wikipedia.org/wiki/Radioisotope) have been characterized; the most stable, [60Co](https://en.wikipedia.org/wiki/Cobalt-60) has a [half-life](https://en.wikipedia.org/wiki/Half-life) of 5.2714 years, and 57Co has a half-life of 271.8 days, 56Co a half-life of 77.27 days, and 58Co a half-life of 70.86 days. All the other [radioactive](https://en.wikipedia.org/wiki/Radioactive) isotopes of cobalt have half-lives shorter than 18 hours, and in most cases shorter than 1 second. This element also has 4 [meta states](https://en.wikipedia.org/wiki/Meta_state), all of which have half-lives shorter than 15 minutes.[[24]](https://en.wikipedia.org/wiki/Cobalt#cite_note-nubase-24)

The isotopes of cobalt range in [atomic weight](https://en.wikipedia.org/wiki/Atomic_weight) from 50 [u](https://en.wikipedia.org/wiki/Atomic_mass_unit) (50Co) to 73 u (73Co). The primary [decay mode](https://en.wikipedia.org/wiki/Decay_mode) for isotopes with atomic mass unit values less than that of the most abundant stable isotope, 59Co, is [electron capture](https://en.wikipedia.org/wiki/Electron_capture) and the primary mode of decay in isotopes with atomic mass greater than 59 atomic mass units is [beta decay](https://en.wikipedia.org/wiki/Beta_decay). The primary [decay products](https://en.wikipedia.org/wiki/Decay_product) below 59Co are element 26 ([iron](https://en.wikipedia.org/wiki/Iron)) isotopes; above that the decay products are element 28 (nickel) isotopes.[[24]](https://en.wikipedia.org/wiki/Cobalt#cite_note-nubase-24)

**History**

[](https://en.wikipedia.org/wiki/File:Early_blue_and_white_ware_circa_1335_Jingdezhen.jpg)

Early Chinese blue and white porcelain, manufactured c. 1335

Cobalt compounds have been used for centuries to impart a rich blue color to [glass](https://en.wikipedia.org/wiki/Glass), [glazes](https://en.wikipedia.org/wiki/Ceramic_glaze), and [ceramics](https://en.wikipedia.org/wiki/Ceramics_(art)). Cobalt has been detected in Egyptian sculpture, Persian jewelry from the third millennium BC, in the ruins of [Pompeii](https://en.wikipedia.org/wiki/Pompeii), destroyed in 79 AD, and in China, dating from the [Tang dynasty](https://en.wikipedia.org/wiki/Tang_dynasty) (618–907 AD) and the [Ming dynasty](https://en.wikipedia.org/wiki/Ming_dynasty) (1368–1644 AD).[[25]](https://en.wikipedia.org/wiki/Cobalt#cite_note-25)

Cobalt has been used to color glass since the [Bronze Age](https://en.wikipedia.org/wiki/Bronze_Age). The excavation of the [Uluburun shipwreck](https://en.wikipedia.org/wiki/Uluburun_shipwreck) yielded an ingot of blue glass, cast during the 14th century BC.[[26]](https://en.wikipedia.org/wiki/Cobalt#cite_note-Pulak-26)[[27]](https://en.wikipedia.org/wiki/Cobalt#cite_note-27) Blue glass from Egypt was either colored with copper, iron, or cobalt. The oldest cobalt-colored glass is from the [eighteenth dynasty of Egypt](https://en.wikipedia.org/wiki/Eighteenth_dynasty_of_Egypt) (1550–1292 BC). The source for the cobalt the Egyptians used is not known.[[28]](https://en.wikipedia.org/wiki/Cobalt#cite_note-28)[[29]](https://en.wikipedia.org/wiki/Cobalt#cite_note-29)

The word *cobalt* is derived from the German *kobalt*, from [*kobold*](https://en.wikipedia.org/wiki/Kobold) meaning "goblin", a superstitious term used for the [ore](https://en.wikipedia.org/wiki/Ore) of cobalt by miners. The first attempts to smelt those ores for copper or nickel failed, yielding simply powder (cobalt(II) oxide) instead. Because the primary ores of cobalt always contain arsenic, smelting the ore oxidized the arsenic into the highly toxic and volatile [arsenic oxide](https://en.wikipedia.org/wiki/Arsenic(III)_oxide), adding to the notoriety of the ore.[[30]](https://en.wikipedia.org/wiki/Cobalt#cite_note-met1863-30)

Swedish chemist [Georg Brandt](https://en.wikipedia.org/wiki/Georg_Brandt) (1694–1768) is credited with discovering cobalt circa 1735, showing it to be a previously unknown element, different from bismuth and other traditional metals. Brandt called it a new "semi-metal".[[31]](https://en.wikipedia.org/wiki/Cobalt#cite_note-31)[[32]](https://en.wikipedia.org/wiki/Cobalt#cite_note-Wang-32) He showed that compounds of cobalt metal were the source of the blue color in glass, which previously had been attributed to the [bismuth](https://en.wikipedia.org/wiki/Bismuth) found with cobalt. Cobalt became the first metal to be discovered since the pre-historical period. All other known metals (iron, copper, silver, gold, zinc, mercury, tin, lead and bismuth) had no recorded discoverers.[[33]](https://en.wikipedia.org/wiki/Cobalt#cite_note-Weeks-33)

During the 19th century, a significant part of the world's production of [cobalt blue](https://en.wikipedia.org/wiki/Cobalt_blue) (a dye made with cobalt compounds and alumina) and [smalt](https://en.wikipedia.org/wiki/Smalt) ([cobalt glass](https://en.wikipedia.org/wiki/Cobalt_glass) powdered for use for pigment purposes in ceramics and painting) was carried out at the Norwegian [Blaafarveværket](https://en.wikipedia.org/wiki/Blaafarvev%C3%A6rket).[[34]](https://en.wikipedia.org/wiki/Cobalt#cite_note-34)[[35]](https://en.wikipedia.org/wiki/Cobalt#cite_note-35) The first mines for the production of smalt in the 16th century were located in Norway, Sweden, [Saxony](https://en.wikipedia.org/wiki/Saxony) and Hungary. With the discovery of cobalt ore in [New Caledonia](https://en.wikipedia.org/wiki/New_Caledonia) in 1864, the mining of cobalt in Europe declined. With the discovery of ore deposits in [Ontario](https://en.wikipedia.org/wiki/Ontario), Canada in 1904 and the discovery of even larger deposits in the [Katanga Province](https://en.wikipedia.org/wiki/Katanga_Province) in the [Congo](https://en.wikipedia.org/wiki/DR_Congo) in 1914, the mining operations shifted again.[[30]](https://en.wikipedia.org/wiki/Cobalt#cite_note-met1863-30) When the [Shaba conflict](https://en.wikipedia.org/wiki/Shaba_II) started in 1978, the copper mines of Katanga Province nearly stopped production.[[36]](https://en.wikipedia.org/wiki/Cobalt#cite_note-USGSnonfuel-36)[[37]](https://en.wikipedia.org/wiki/Cobalt#cite_note-glres-37) The impact on the world cobalt economy from this conflict was smaller than expected: cobalt is a rare metal, the pigment is highly toxic, and the industry had already established effective ways for recycling cobalt materials. In some cases, industry was able to change to cobalt-free alternatives.[[36]](https://en.wikipedia.org/wiki/Cobalt#cite_note-USGSnonfuel-36)[[37]](https://en.wikipedia.org/wiki/Cobalt#cite_note-glres-37)

In 1938, John Livingood and [Glenn T. Seaborg](https://en.wikipedia.org/wiki/Glenn_T._Seaborg) discovered the radioisotope [cobalt-60](https://en.wikipedia.org/wiki/Cobalt-60).[[38]](https://en.wikipedia.org/wiki/Cobalt#cite_note-38) This isotope was famously used at [Columbia University](https://en.wikipedia.org/wiki/Columbia_University) in the 1950s to establish [parity](https://en.wikipedia.org/wiki/Parity_(physics)) violation in radioactive [beta decay](https://en.wikipedia.org/wiki/Beta_decay).[[39]](https://en.wikipedia.org/wiki/Cobalt#cite_note-39)[[40]](https://en.wikipedia.org/wiki/Cobalt#cite_note-40)

After World War II, the US wanted to guarantee the supply of cobalt ore for military uses (as the Germans had been doing) and prospected for cobalt within the U.S. border. An adequate supply of the ore was found in Idaho near [Blackbird canyon](https://en.wikipedia.org/wiki/Blackbird_Mine) in the side of a mountain. The firm Calera Mining Company started production at the site.[[41]](https://en.wikipedia.org/wiki/Cobalt#cite_note-41)

**Occurrence**

The stable form of cobalt is produced in [supernovas](https://en.wikipedia.org/wiki/Supernova) through the [r-process](https://en.wikipedia.org/wiki/R-process).[[42]](https://en.wikipedia.org/wiki/Cobalt#cite_note-42) It comprises [0.0029% of the Earth's crust](https://en.wikipedia.org/wiki/Abundance_of_the_chemical_elements). Free cobalt (the [native metal](https://en.wikipedia.org/wiki/Native_metal)) is not found on Earth because of the oxygen in the atmosphere and the chlorine in the ocean. Both are abundant enough in the upper layers of the Earth's crust to prevent native metal cobalt from forming. Except as recently delivered in meteoric iron, pure cobalt in native metal form is unknown on Earth. The element has a medium abundance but natural compounds of cobalt are numerous and all amounts of cobalt compounds are found in most rocks, soil, plants, and animals.

In nature, cobalt is frequently associated with [nickel](https://en.wikipedia.org/wiki/Nickel). Both are characteristic components of [meteoric iron](https://en.wikipedia.org/wiki/Meteoric_iron), though cobalt is much less abundant in iron meteorites than nickel. As with nickel, cobalt in meteoric iron [alloys](https://en.wikipedia.org/wiki/Alloy) may have been well enough protected from oxygen and moisture to remain as the free (but alloyed) metal,[[43]](https://en.wikipedia.org/wiki/Cobalt#cite_note-43) though neither element is seen in that form in the ancient terrestrial crust.

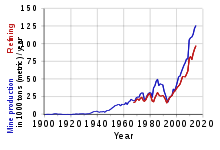
Cobalt in compound form occurs in copper and nickel minerals. It is the major metallic component that combines with [sulfur](https://en.wikipedia.org/wiki/Sulfur) and arsenic in the sulfidic [cobaltite](https://en.wikipedia.org/wiki/Cobaltite) (CoAsS), [safflorite](https://en.wikipedia.org/wiki/Safflorite) (CoAs2), [glaucodot](https://en.wikipedia.org/wiki/Glaucodot) ((Co,Fe)AsS), and [skutterudite](https://en.wikipedia.org/wiki/Skutterudite) (CoAs3) minerals.[[11]](https://en.wikipedia.org/wiki/Cobalt#cite_note-HollemanAF-11) The mineral [cattierite](https://en.wikipedia.org/wiki/Cattierite) is similar to [pyrite](https://en.wikipedia.org/wiki/Pyrite) and occurs together with [vaesite](https://en.wikipedia.org/wiki/Vaesite) in the copper deposits of [Katanga Province](https://en.wikipedia.org/wiki/Katanga_Province).[[44]](https://en.wikipedia.org/wiki/Cobalt#cite_note-44) When it reaches the atmosphere, [weathering](https://en.wikipedia.org/wiki/Weathering) occurs; the sulfide minerals oxidize and form pink [erythrite](https://en.wikipedia.org/wiki/Erythrite) ("cobalt glance": [Co3(AsO4)2·8H2O](https://en.wikipedia.org/wiki/Erythrite)) and [spherocobaltite](https://en.wikipedia.org/wiki/Spherocobaltite) (CoCO3).[[45]](https://en.wikipedia.org/wiki/Cobalt#cite_note-45)[[46]](https://en.wikipedia.org/wiki/Cobalt#cite_note-46)

Cobalt is also a constituent of [tobacco smoke](https://en.wikipedia.org/wiki/Tobacco_smoke).[[47]](https://en.wikipedia.org/wiki/Cobalt#cite_note-TalhoutSchulz2011-47) The [tobacco plant](https://en.wikipedia.org/wiki/Tobacco_plant) readily absorbs and accumulates [heavy metals](https://en.wikipedia.org/wiki/Heavy_metals) like cobalt from the surrounding soil in its leaves. These are subsequently inhaled during [tobacco smoking](https://en.wikipedia.org/wiki/Tobacco_smoking).[[48]](https://en.wikipedia.org/wiki/Cobalt#cite_note-48)

**Production**

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

Cobalt ore

[](https://en.wikipedia.org/wiki/File:Cobalt_-_world_production_trend.svg)

World production trend

See also: [Cobalt extraction techniques](https://en.wikipedia.org/wiki/Cobalt_extraction_techniques)

| Cobalt mine production (2017) and reserves in tonnes according to [USGS](https://en.wikipedia.org/wiki/United_States_Geological_Survey)[[49]](https://en.wikipedia.org/wiki/Cobalt#cite_note-minerals.usgs.gov-49) | | |
| --- | --- | --- |
| **Country** | **Production** | **Reserves** |
| https://upload.wikimedia.org/wikipedia/commons/thumb/6/6f/Flag_of_the_Democratic_Republic_of_the_Congo.svg/20px-Flag_of_the_Democratic_Republic_of_the_Congo.svg.png [DR Congo](https://en.wikipedia.org/wiki/Democratic_Republic_of_the_Congo) | 64,000 | 3,500,000 |
| https://upload.wikimedia.org/wikipedia/en/thumb/f/f3/Flag_of_Russia.svg/23px-Flag_of_Russia.svg.png [Russia](https://en.wikipedia.org/wiki/Russia) | 5,600 | 250,000 |
| https://upload.wikimedia.org/wikipedia/en/thumb/b/b9/Flag_of_Australia.svg/23px-Flag_of_Australia.svg.png [Australia](https://en.wikipedia.org/wiki/Australia) | 5,000 | 1,200,000 |
| https://upload.wikimedia.org/wikipedia/en/thumb/c/cf/Flag_of_Canada.svg/23px-Flag_of_Canada.svg.png [Canada](https://en.wikipedia.org/wiki/Canada) | 4,300 | 250,000 |
| https://upload.wikimedia.org/wikipedia/commons/thumb/b/bd/Flag_of_Cuba.svg/23px-Flag_of_Cuba.svg.png [Cuba](https://en.wikipedia.org/wiki/Cuba) | 4,200 | 500,000 |
| https://upload.wikimedia.org/wikipedia/commons/thumb/9/99/Flag_of_the_Philippines.svg/23px-Flag_of_the_Philippines.svg.png [Philippines](https://en.wikipedia.org/wiki/Philippines) | 4,000 | 280,000 |
| https://upload.wikimedia.org/wikipedia/commons/thumb/b/bc/Flag_of_Madagascar.svg/23px-Flag_of_Madagascar.svg.png [Madagascar](https://en.wikipedia.org/wiki/Madagascar) | 3,800 | 150,000 |
| https://upload.wikimedia.org/wikipedia/commons/thumb/e/e3/Flag_of_Papua_New_Guinea.svg/20px-Flag_of_Papua_New_Guinea.svg.png [Papua New Guinea](https://en.wikipedia.org/wiki/Papua_New_Guinea) | 3,200 | 51,000 |
| https://upload.wikimedia.org/wikipedia/commons/thumb/0/06/Flag_of_Zambia.svg/23px-Flag_of_Zambia.svg.png [Zambia](https://en.wikipedia.org/wiki/Zambia) | 2,900 | 270,000 |
| https://upload.wikimedia.org/wikipedia/commons/thumb/6/66/Flag_of_FLNKS.svg/23px-Flag_of_FLNKS.svg.png [New Caledonia](https://en.wikipedia.org/wiki/New_Caledonia) | 2,800 | - |
| https://upload.wikimedia.org/wikipedia/commons/thumb/a/af/Flag_of_South_Africa.svg/23px-Flag_of_South_Africa.svg.png [South Africa](https://en.wikipedia.org/wiki/South_Africa) | 2,500 | 29,000 |
| https://upload.wikimedia.org/wikipedia/en/thumb/a/a4/Flag_of_the_United_States.svg/23px-Flag_of_the_United_States.svg.png [United States](https://en.wikipedia.org/wiki/United_States) | 650 | 23,000 |
| Other countries | 5,900 | 560,000 |
| **World total** | **110,000** | **7,100,000** |

The main ores of cobalt are [cobaltite](https://en.wikipedia.org/wiki/Cobaltite), erythrite, [glaucodot](https://en.wikipedia.org/wiki/Glaucodot) and [skutterudite](https://en.wikipedia.org/wiki/Skutterudite) (see above), but most cobalt is obtained by reducing the cobalt [by-products](https://en.wikipedia.org/wiki/By-product) of nickel and [copper](https://en.wikipedia.org/wiki/Copper) mining and [smelting](https://en.wikipedia.org/wiki/Smelting).[[50]](https://en.wikipedia.org/wiki/Cobalt#cite_note-YB2006-50)[[51]](https://en.wikipedia.org/wiki/Cobalt#cite_note-CR2008-51)

Since cobalt is generally produced as a by-product, the supply of cobalt depends to a great extent on the economic feasibility of copper and nickel mining in a given market. Demand for cobalt was projected to grow 6% in 2017.[[52]](https://en.wikipedia.org/wiki/Cobalt#cite_note-ft-52)

Several methods exist to separate cobalt from copper and nickel, depending on the concentration of cobalt and the exact composition of the used [ore](https://en.wikipedia.org/wiki/Ore). One method is [froth flotation](https://en.wikipedia.org/wiki/Froth_flotation), in which [surfactants](https://en.wikipedia.org/wiki/Surfactant) bind to different ore components, leading to an enrichment of cobalt ores. Subsequent [roasting](https://en.wikipedia.org/wiki/Roasting_(metallurgy)) converts the ores to [cobalt sulfate](https://en.wikipedia.org/wiki/Cobalt_sulfate), and the copper and the iron are oxidized to the oxide. [Leaching](https://en.wikipedia.org/wiki/Leaching_(metallurgy)) with water extracts the sulfate together with the [arsenates](https://en.wikipedia.org/wiki/Arsenate). The residues are further leached with [sulfuric acid](https://en.wikipedia.org/wiki/Sulfuric_acid), yielding a solution of copper sulfate. Cobalt can also be leached from the [slag](https://en.wikipedia.org/wiki/Slag) of copper smelting.[[53]](https://en.wikipedia.org/wiki/Cobalt#cite_note-53)

The products of the above-mentioned processes are transformed into the cobalt oxide (Co3O4). This oxide is reduced to metal by the [aluminothermic reaction](https://en.wikipedia.org/wiki/Aluminothermic_reaction) or reduction with carbon in a [blast furnace](https://en.wikipedia.org/wiki/Blast_furnace).[[11]](https://en.wikipedia.org/wiki/Cobalt#cite_note-HollemanAF-11)

**Cobalt extraction**

The [United States Geological Survey](https://en.wikipedia.org/wiki/United_States_Geological_Survey) estimates world reserves of cobalt at 7,100,000 metric tons.[[54]](https://en.wikipedia.org/wiki/Cobalt#cite_note-USGSJan2016-54) The [Democratic Republic of the Congo](https://en.wikipedia.org/wiki/Democratic_Republic_of_the_Congo) (DRC) currently produces 63% of the world’s cobalt. This market share may reach 73% by 2025 if planned expansions by mining producers like [Glencore](https://en.wikipedia.org/wiki/Glencore) Plc take place as expected. But by 2030, global demand could be 47 times more than it was in 2017, Bloomberg New Energy Finance has estimated.[[55]](https://en.wikipedia.org/wiki/Cobalt#cite_note-55)

Changes that Congo made to mining laws in 2002 led did attract investment in Congolese copper and cobalt projects. However Glencore dominates the coltan market in DRC. Its Mutanda mine shipped 24,500 tons of cobalt from its Mutanda mine last year, 40% of Congo DRC’s output and nearly a quarter of global production. T Glencore’s Katanga Mining project is resuming as well and should produce 300,000 tons of copper and 20,000 tons of cobalt by 2019, according to Glencore.[[52]](https://en.wikipedia.org/wiki/Cobalt#cite_note-ft-52)

**Democratic Republic of the Congo**

See also: [Conflict minerals](https://en.wikipedia.org/wiki/Conflict_minerals), [Child labor](https://en.wikipedia.org/wiki/Child_labor), and [strip mining](https://en.wikipedia.org/wiki/Strip_mining)

In 2005, the top producer of cobalt was the copper deposits in the [Democratic Republic of the Congo](https://en.wikipedia.org/wiki/Democratic_Republic_of_the_Congo)'s [Katanga Province](https://en.wikipedia.org/wiki/Katanga_Province). Formerly Shaba province, the area had almost 40% of global reserves, reported the [British Geological Survey](https://en.wikipedia.org/wiki/British_Geological_Survey) in 2009.[[56]](https://en.wikipedia.org/wiki/Cobalt#cite_note-56) By 2015, Democratic Republic of the Congo (DRC) supplied 60% of world cobalt production, 32,000 tons at $20,000 to $26,000 per ton. Recent growth in production could at least partly be due to how low mining production fell during DRC Congo's very violent civil wars in the early 2000s, or to the changes the country made to its Mining Code in 2002 to encourage foreign and multinational investment and which did bring in a number of investors, including [Glencore](https://en.wikipedia.org/wiki/Glencore). Three of its current Congo projects [Artisanal mining](https://en.wikipedia.org/wiki/Artisanal_mining) supplied 10% to 25% of the DRC production.[[57]](https://en.wikipedia.org/wiki/Cobalt#cite_note-wpDRC1-57) Some 100,000 cobalt miners in Congo DRC use hand tools to dig hundreds of feet, with little planning and fewer safety measures, say workers and government and NGO officials, as well as [Washington Post](https://en.wikipedia.org/wiki/Washington_Post) reporters' observations on visits to isolated mines. The lack of safety precautions frequently causes injuries or death.[[58]](https://en.wikipedia.org/wiki/Cobalt#cite_note-58) Mining pollutes the vicinity and exposes local wildlife and indigenous communities to toxic metals thought to cause birth defects and breathing difficulties, according to health officials.[[59]](https://en.wikipedia.org/wiki/Cobalt#cite_note-59)

Human rights activists have alleged, and [investigative journalism](https://en.wikipedia.org/wiki/Investigative_journalism) reported confirmation,[[60]](https://en.wikipedia.org/wiki/Cobalt#cite_note-60)[[61]](https://en.wikipedia.org/wiki/Cobalt#cite_note-61) that [child labor](https://en.wikipedia.org/wiki/Child_labor) is used in mining cobalt from African [artisanal mines](https://en.wikipedia.org/wiki/Artisanal_mining).[[57]](https://en.wikipedia.org/wiki/Cobalt#cite_note-wpDRC1-57)[[62]](https://en.wikipedia.org/wiki/Cobalt#cite_note-62) This revelation prompted cell phone maker [Apple Inc.](https://en.wikipedia.org/wiki/Apple_Inc.), on March 3, 2017, to stop buying ore from suppliers such as [Zhejiang Huayou Cobalt](https://en.wikipedia.org/wiki/Zhejiang_Huayou_Cobalt) who source from artisanal mines in the DRC, and begin using only suppliers that are verified to meet its workplace standards.[[63]](https://en.wikipedia.org/wiki/Cobalt#cite_note-63)[[64]](https://en.wikipedia.org/wiki/Cobalt#cite_note-64)

The political and ethnic dynamics of the region have in the past caused horrific outbreaks of violence and years of armed conflict and displaced populations. This instability affected the price of cobalt and also created perverse incentives for the combattants in the First and Second Congo Wars to prolong the fighting, since access to diamond mines and other valuable resources helped to finance their military goals—which frequently amounteed to genocide—and also enriched the fighters themselves. While DR Congo has in the 2010s not recently been invaded by neighboring military forces, some of the richest mineral deposits adjoin areas where Tutsis and Hutus still frequently clash, unrest continues although on a smaller scale and refugees still flee outbreaks of violence.[[65]](https://en.wikipedia.org/wiki/Cobalt#cite_note-65)

Cobalt extracted from small Congolese [artisanal mining](https://en.wikipedia.org/wiki/Artisanal_mining) endeavors in 2007 supplied a single Chinese company, Congo DongFang International Mining. A subsidiary of [Zhejiang Huayou Cobalt](https://en.wikipedia.org/wiki/Zhejiang_Huayou_Cobalt), one of the world’s largest cobalt producers, Congo DongFang supplied cobalt to some of the world’s largest battery manufacturers, who produced batteries for ubiquitous products like the Apple [iPhones](https://en.wikipedia.org/wiki/IPhone). Corporate pieties about an ethical [supply chain](https://en.wikipedia.org/wiki/Supply_chain) were thus met with some incredulity. A number of observers have called for tech corporations and other manufacturers to avoid sourcing conflict metals in Central Africa at all rather than risk enabling the financial exploitation, [human rights](https://en.wikipedia.org/wiki/Human_rights) abuses like kidnappings for [unfree labor](https://en.wikipedia.org/wiki/Unfree_labor), environmental devastation and the human toll of violence, poverty and toxic conditions.

The [Mukondo Mountain](https://en.wikipedia.org/wiki/Mukondo_Mountain) project, operated by the [Central African Mining and Exploration Company](https://en.wikipedia.org/wiki/Central_African_Mining_and_Exploration_Company) (CAMEC) in [Katanga Province](https://en.wikipedia.org/wiki/Katanga_Province), may be the richest cobalt reserve in the world. It produced an estimated one third of the total global coval production in 2008.[[66]](https://en.wikipedia.org/wiki/Cobalt#cite_note-IntMining200807-66) In July 2009, CAMEC announced a long-term agreement to deliver its entire annual [production](https://en.wikipedia.org/wiki/Production_(economics)) of cobalt concentrate from Mukondo Mountain to Zhejiang Galico Cobalt & Nickel Materials of China.[[67]](https://en.wikipedia.org/wiki/Cobalt#cite_note-67)

In February 2018, global asset management firm [AllianceBernstein](https://en.wikipedia.org/wiki/AllianceBernstein) defined the DRC as economically "the [Saudi Arabia](https://en.wikipedia.org/wiki/Saudi_Arabia) of the electric vehicle age," due to its cobalt resources, as essential to the [lithium-ion batteries](https://en.wikipedia.org/wiki/Lithium-ion_battery) that drive [electric vehicles](https://en.wikipedia.org/wiki/Electric_vehicle).[[68]](https://en.wikipedia.org/wiki/Cobalt#cite_note-68)

On March 9, 2018, President [Joseph Kabila](https://en.wikipedia.org/wiki/Joseph_Kabila) updated the 2002 mining code, increasing royalty charges and declaring cobalt and [coltan](https://en.wikipedia.org/wiki/Coltan) "strategic metals".[[69]](https://en.wikipedia.org/wiki/Cobalt#cite_note-69)[[70]](https://en.wikipedia.org/wiki/Cobalt#cite_note-70)

**Canada**

In 2017, some exploration companies were planning to survey old silver and cobalt mines in the area of [Cobalt, Ontario](https://en.wikipedia.org/wiki/Cobalt,_Ontario) where significant deposits are believed to lie.[[71]](https://en.wikipedia.org/wiki/Cobalt#cite_note-71) The mayor of Cobalt stated that the people of Cobalt welcomed new mining endeavours and pointed out that the local work force is peaceful and English-speaking, and good infrastructure would allow much easier sourcing of spare parts for the equipment or other supplies than were to be found in conflict-zones.

**Applications**

Cobalt has been used in production of high-performance alloys.[[50]](https://en.wikipedia.org/wiki/Cobalt#cite_note-YB2006-50)[[51]](https://en.wikipedia.org/wiki/Cobalt#cite_note-CR2008-51) It can also be used to make rechargeable batteries, and the advent of electric vehicles and their success with consumers probably has a great deal to do with the DRC's soaring production. Other important factors were the 2002 Mining Code, which encouraged investment by foreign and transnational corporations such as Glencore, and the end of the First and Second Congo Wars.

**Alloys**

Cobalt-based [superalloys](https://en.wikipedia.org/wiki/Superalloy) have historically consumed most of the cobalt produced.[[50]](https://en.wikipedia.org/wiki/Cobalt#cite_note-YB2006-50)[[51]](https://en.wikipedia.org/wiki/Cobalt#cite_note-CR2008-51) The temperature stability of these alloys makes them suitable for turbine blades for [gas turbines](https://en.wikipedia.org/wiki/Gas_turbine) and aircraft [jet engines](https://en.wikipedia.org/wiki/Jet_engine), although nickel-based [single-crystal](https://en.wikipedia.org/wiki/Single-crystal) alloys surpass them in performance.[[72]](https://en.wikipedia.org/wiki/Cobalt#cite_note-super-72) Cobalt-based alloys are also [corrosion](https://en.wikipedia.org/wiki/Corrosion)- and wear-resistant, making them, like [titanium](https://en.wikipedia.org/wiki/Titanium), useful for making orthopedic [implants](https://en.wikipedia.org/wiki/Implant_(medicine)) that don't wear down over time. The development of wear-resistant cobalt alloys started in the first decade of the 20th century with the [stellite](https://en.wikipedia.org/wiki/Stellite) alloys, containing chromium with varying quantities of tungsten and carbon. Alloys with [chromium](https://en.wikipedia.org/wiki/Chromium) and [tungsten carbides](https://en.wikipedia.org/wiki/Tungsten_carbide) are very hard and wear-resistant.[[73]](https://en.wikipedia.org/wiki/Cobalt#cite_note-73) Special cobalt-chromium-[molybdenum](https://en.wikipedia.org/wiki/Molybdenum) alloys like [Vitallium](https://en.wikipedia.org/wiki/Vitallium) are used for [prosthetic](https://en.wikipedia.org/wiki/Prosthesis) parts (hip and knee replacements).[[74]](https://en.wikipedia.org/wiki/Cobalt#cite_note-74) Cobalt alloys are also used for [dental](https://en.wikipedia.org/wiki/Dental_implant) prosthetics as a useful substitute for nickel, which may be allergenic.[[75]](https://en.wikipedia.org/wiki/Cobalt#cite_note-75) Some [high-speed steels](https://en.wikipedia.org/wiki/High-speed_steel) also contain cobalt for increased heat and wear resistance. The special alloys of aluminium, nickel, cobalt and iron, known as [Alnico](https://en.wikipedia.org/wiki/Alnico), and of samarium and cobalt ([samarium-cobalt magnet](https://en.wikipedia.org/wiki/Samarium-cobalt_magnet)) are used in [permanent magnets](https://en.wikipedia.org/wiki/Permanent_magnets).[[76]](https://en.wikipedia.org/wiki/Cobalt#cite_note-Alnico-76) It is also alloyed with 95% [platinum](https://en.wikipedia.org/wiki/Platinum) for jewelry, yielding an alloy suitable for fine casting, which is also slightly magnetic.[[77]](https://en.wikipedia.org/wiki/Cobalt#cite_note-77)

**Batteries**

[Lithium cobalt oxide](https://en.wikipedia.org/wiki/Lithium_cobalt_oxide) (LiCoO2) is widely used in [lithium-ion battery](https://en.wikipedia.org/wiki/Lithium-ion_battery) cathodes. The material is composed of cobalt oxide layers with the lithium [intercalated](https://en.wikipedia.org/wiki/Intercalation_(chemistry)). During discharge,[[*clarification needed*](https://en.wikipedia.org/wiki/Wikipedia:Please_clarify)] the lithium is released as lithium ions.[[78]](https://en.wikipedia.org/wiki/Cobalt#cite_note-WhyCo-78) [Nickel-cadmium](https://en.wikipedia.org/wiki/Nickel-cadmium_battery)[[79]](https://en.wikipedia.org/wiki/Cobalt#cite_note-bat1-79) (NiCd) and [nickel metal hydride](https://en.wikipedia.org/wiki/Nickel_metal_hydride_battery)[[80]](https://en.wikipedia.org/wiki/Cobalt#cite_note-80) (NiMH) batteries also include cobalt to improve the oxidation of nickel in the battery.[[79]](https://en.wikipedia.org/wiki/Cobalt#cite_note-bat1-79) Transparency Market Research estimated the global lithium-ion battery market at $30 billion in 2015 and predicted an increase to over US$75 billion by 2024.[[81]](https://en.wikipedia.org/wiki/Cobalt#cite_note-81)

Although in 2018 most cobalt in batteries was used in a mobile device,[[82]](https://en.wikipedia.org/wiki/Cobalt#cite_note-82) a more recent application for cobalt is rechargeable batteries for electric cars. This industry has increased five-fold in its demand for cobalt, which makes it urgent to find new raw materials in more stable areas of the world.[[83]](https://en.wikipedia.org/wiki/Cobalt#cite_note-cleantechnica1-83) Demand is expected to continue or increase as the prevalence of electric vehicles increases.[[84]](https://en.wikipedia.org/wiki/Cobalt#cite_note-84) Exploration in 2016–2017 included the area around [Cobalt, Ontario](https://en.wikipedia.org/wiki/Cobalt,_Ontario), an area where many silver mines ceased operation decades ago.[[83]](https://en.wikipedia.org/wiki/Cobalt#cite_note-cleantechnica1-83)

Since child and slave labor have been repeatedly reported in coltan mining, primarily in the artisanal mines of DR Congo, tech companies seeking an ethical supply chain have faced shortages of this raw material and[[85]](https://en.wikipedia.org/wiki/Cobalt#cite_note-85) the price of cobalt metal reached a nine-year high in October 2017, more than US$30 a pound, versus US$10 in late 2015.[[86]](https://en.wikipedia.org/wiki/Cobalt#cite_note-86)

**Catalysts**

Several cobalt compounds are oxidation catalysts. Cobalt acetate is used to convert [xylene](https://en.wikipedia.org/wiki/Xylene) to [terephthalic acid](https://en.wikipedia.org/wiki/Terephthalic_acid), the precursor of the bulk polymer [polyethylene terephthalate](https://en.wikipedia.org/wiki/Polyethylene_terephthalate). Typical catalysts are the cobalt [carboxylates](https://en.wikipedia.org/wiki/Carboxylate) (known as cobalt soaps). They are also used in paints, varnishes, and inks as "drying agents" through the oxidation of [drying oils](https://en.wikipedia.org/wiki/Drying_oils).[[78]](https://en.wikipedia.org/wiki/Cobalt#cite_note-WhyCo-78) The same carboxylates are used to improve the adhesion between steel and rubber in steel-belted radial tires. In addition they are used as accelerators in [polyester resin](https://en.wikipedia.org/wiki/Polyester_resin) systems.

Cobalt-based catalysts are used in reactions involving [carbon monoxide](https://en.wikipedia.org/wiki/Carbon_monoxide). Cobalt is also a catalyst in the [Fischer–Tropsch process](https://en.wikipedia.org/wiki/Fischer%E2%80%93Tropsch_process) for the [hydrogenation](https://en.wikipedia.org/wiki/Hydrogenation) of carbon monoxide into liquid fuels.[[87]](https://en.wikipedia.org/wiki/Cobalt#cite_note-87) [Hydroformylation](https://en.wikipedia.org/wiki/Hydroformylation) of [alkenes](https://en.wikipedia.org/wiki/Alkene) often uses [cobalt octacarbonyl](https://en.wikipedia.org/wiki/Cobalt_octacarbonyl) as a catalyst,[[88]](https://en.wikipedia.org/wiki/Cobalt#cite_note-88) although it is often replaced by more efficient iridium- and rhodium-based catalysts, e.g. the [Cativa process](https://en.wikipedia.org/wiki/Cativa_process).

The [hydrodesulfurization](https://en.wikipedia.org/wiki/Hydrodesulfurization) of [petroleum](https://en.wikipedia.org/wiki/Petroleum) uses a catalyst derived from cobalt and molybdenum. This process helps to clean petroleum of sulfur impurities that interfere with the refining of liquid fuels.[[78]](https://en.wikipedia.org/wiki/Cobalt#cite_note-WhyCo-78)

**Pigments and coloring**

[](https://en.wikipedia.org/wiki/File:Bristol.blue.glass.arp.750pix.jpg)

Cobalt blue glass

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

Cobalt-colored glass

Before the 19th century, cobalt was predominantly used as a pigment. It has been used since the Middle Ages to make [smalt](https://en.wikipedia.org/wiki/Smalt), a blue-colored glass. Smalt is produced by melting a mixture of roasted mineral [smaltite](https://en.wikipedia.org/wiki/Smaltite), [quartz](https://en.wikipedia.org/wiki/Quartz) and [potassium carbonate](https://en.wikipedia.org/wiki/Potassium_carbonate), which yields a dark blue silicate glass, which is finely ground after the production.[[89]](https://en.wikipedia.org/wiki/Cobalt#cite_note-89) Smalt was widely used to color glass and as pigment for paintings.[[90]](https://en.wikipedia.org/wiki/Cobalt#cite_note-90) In 1780, [Sven Rinman](https://en.wikipedia.org/wiki/Sven_Rinman) discovered [cobalt green](https://en.wikipedia.org/wiki/Cobalt_green), and in 1802 [Louis Jacques Thénard](https://en.wikipedia.org/wiki/Louis_Jacques_Th%C3%A9nard) discovered cobalt blue.[[91]](https://en.wikipedia.org/wiki/Cobalt#cite_note-91) Cobalt pigments such as [cobalt blue](https://en.wikipedia.org/wiki/Cobalt_blue) (cobalt aluminate), [cerulean](https://en.wikipedia.org/wiki/Cerulean) blue (cobalt(II) stannate), various hues of [cobalt green](https://en.wikipedia.org/wiki/Cobalt_green) (a mixture of [cobalt(II) oxide](https://en.wikipedia.org/wiki/Cobalt(II)_oxide) and [zinc oxide](https://en.wikipedia.org/wiki/Zinc_oxide)), and cobalt violet ([cobalt phosphate](https://en.wikipedia.org/wiki/Cobalt_phosphate)) are used as artist's pigments because of their superior chromatic stability.[[92]](https://en.wikipedia.org/wiki/Cobalt#cite_note-92)[[93]](https://en.wikipedia.org/wiki/Cobalt#cite_note-Venetskii-93) [Aureolin](https://en.wikipedia.org/wiki/Aureolin) (cobalt yellow) is now largely replaced by more lightfast[[*clarification needed*](https://en.wikipedia.org/wiki/Wikipedia:Please_clarify)] yellow pigments.

**Radioisotopes**

[Cobalt-60](https://en.wikipedia.org/wiki/Cobalt-60) (Co-60 or 60Co) is useful as a gamma-ray source because they can be produced in predictable quantity and high [activity](https://en.wikipedia.org/wiki/Activity_(radioactivity)) by bombarding cobalt with [neutrons](https://en.wikipedia.org/wiki/Neutron). It produces [gamma rays](https://en.wikipedia.org/wiki/Gamma_ray) with energies of 1.17 and 1.33 [MeV](https://en.wikipedia.org/wiki/MeV).[[24]](https://en.wikipedia.org/wiki/Cobalt#cite_note-nubase-24)[[94]](https://en.wikipedia.org/wiki/Cobalt#cite_note-94)

Cobalt is used in [external beam radiotherapy](https://en.wikipedia.org/wiki/External_beam_radiotherapy), sterilization of medical supplies and medical waste, radiation treatment of [foods for sterilization](https://en.wikipedia.org/wiki/Food_irradiation) (cold [pasteurization](https://en.wikipedia.org/wiki/Pasteurization)),[[95]](https://en.wikipedia.org/wiki/Cobalt#cite_note-95) [industrial radiography](https://en.wikipedia.org/wiki/Industrial_radiography) (e.g. weld integrity radiographs), density measurements (e.g. concrete density measurements), and tank fill height switches. The metal has the unfortunate property of producing a fine dust, causing problems with [radiation protection](https://en.wikipedia.org/wiki/Radiation_protection). Cobalt from radiotherapy machines has been a serious hazard when not discarded properly, and one of the worst radiation contamination accidents in North America occurred in 1984, when a discarded radiotherapy unit containing cobalt-60 was mistakenly disassembled in a junkyard in Juarez, Mexico.[[96]](https://en.wikipedia.org/wiki/Cobalt#cite_note-96)[[97]](https://en.wikipedia.org/wiki/Cobalt#cite_note-97)

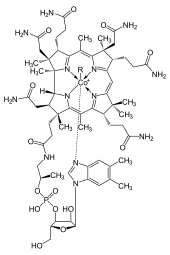
Cobalt-60 has a radioactive half-life of 5.27 years. Loss of potency requires periodic replacement of the source in radiotherapy and is one reason why cobalt machines have been largely replaced by [linear accelerators](https://en.wikipedia.org/wiki/Linear_particle_accelerator) in modern radiation therapy.[[98]](https://en.wikipedia.org/wiki/Cobalt#cite_note-98) [Cobalt-57](https://en.wikipedia.org/wiki/Isotopes_of_cobalt) (Co-57 or 57Co) is a cobalt radioisotope most often used in medical tests, as a radiolabel for vitamin B12 uptake, and for the [Schilling test](https://en.wikipedia.org/wiki/Schilling_test). Cobalt-57 is used as a source in [Mössbauer spectroscopy](https://en.wikipedia.org/wiki/M%C3%B6ssbauer_spectroscopy) and is one of several possible sources in [X-ray fluorescence](https://en.wikipedia.org/wiki/X-ray_fluorescence) devices.[[99]](https://en.wikipedia.org/wiki/Cobalt#cite_note-99)[[100]](https://en.wikipedia.org/wiki/Cobalt#cite_note-100)

[Nuclear weapon designs](https://en.wikipedia.org/wiki/Nuclear_weapon_design) could intentionally incorporate 59Co, some of which would be activated in a [nuclear explosion](https://en.wikipedia.org/wiki/Nuclear_explosion) to produce 60Co. The 60Co, dispersed as [nuclear fallout](https://en.wikipedia.org/wiki/Nuclear_fallout), is sometimes called a [cobalt bomb](https://en.wikipedia.org/wiki/Cobalt_bomb).[[101]](https://en.wikipedia.org/wiki/Cobalt#cite_note-101)

**Other uses**

* Cobalt is used in [electroplating](https://en.wikipedia.org/wiki/Electroplating) for its attractive appearance, hardness, and resistance to [oxidation](https://en.wikipedia.org/wiki/Oxidation);[[102]](https://en.wikipedia.org/wiki/Cobalt#cite_note-102)
* It is also used as a base primer coat for [porcelain](https://en.wikipedia.org/wiki/Porcelain) [enamels](https://en.wikipedia.org/wiki/Vitreous_enamel).[[103]](https://en.wikipedia.org/wiki/Cobalt#cite_note-103)

**Biological role**

[](https://en.wikipedia.org/wiki/File:Cobalamin.svg)

[Cobalamin](https://en.wikipedia.org/wiki/Cobalamin)

[](https://en.wikipedia.org/wiki/File:CSIRO_ScienceImage_10487_Cobalt_deficient_sheep.jpg)

Cobalt-deficient sheep

Cobalt is essential to the metabolism of all [animals](https://en.wikipedia.org/wiki/Animal). It is a key constituent of [cobalamin](https://en.wikipedia.org/wiki/Vitamin_B12), also known as vitamin B12, the primary biological reservoir of cobalt as an [ultratrace element](https://en.wikipedia.org/wiki/Ultratrace_element).[[104]](https://en.wikipedia.org/wiki/Cobalt#cite_note-104)[[105]](https://en.wikipedia.org/wiki/Cobalt#cite_note-105) [Bacteria](https://en.wikipedia.org/wiki/Bacteria) in the stomachs of [ruminant](https://en.wikipedia.org/wiki/Ruminant) animals convert cobalt salts into vitamin B12, a compound which can only be produced by bacteria or [archaea](https://en.wikipedia.org/wiki/Archaea). A minimal presence of cobalt in soils therefore markedly improves the health of [grazing](https://en.wikipedia.org/wiki/Grazing) animals, and an uptake of 0.20 mg/kg a day is recommended because they have no other source of vitamin B12.[[106]](https://en.wikipedia.org/wiki/Cobalt#cite_note-106)

In the early 20th century, during the development of farming on the [North Island Volcanic Plateau](https://en.wikipedia.org/wiki/North_Island_Volcanic_Plateau) of New Zealand, cattle suffered from what was termed "bush sickness". It was discovered that the volcanic soils lacked the cobalt salts essential for the cattle food chain.[[107]](https://en.wikipedia.org/wiki/Cobalt#cite_note-107)[[108]](https://en.wikipedia.org/wiki/Cobalt#cite_note-McDoewel-108)

The "coast disease" of sheep in the [Ninety Mile Desert](https://en.wikipedia.org/wiki/Ninety_Mile_Desert) of the [Southeast](https://en.wikipedia.org/wiki/Limestone_Coast) of [South Australia](https://en.wikipedia.org/wiki/South_Australia) in the 1930s was found to originate in nutritional deficiencies of trace elements cobalt and copper. The cobalt deficiency was overcome by the development of "cobalt bullets", dense pellets of cobalt oxide mixed with clay given orally for lodging in the animal's [rumen](https://en.wikipedia.org/wiki/Rumen).[[*clarification needed*](https://en.wikipedia.org/wiki/Wikipedia:Please_clarify)][[109]](https://en.wikipedia.org/wiki/Cobalt#cite_note-109)[[108]](https://en.wikipedia.org/wiki/Cobalt#cite_note-McDoewel-108)

Proteins based on cobalamin use [corrin](https://en.wikipedia.org/wiki/Corrin) to hold the cobalt. Coenzyme B12 features a reactive C-Co bond that participates in the reactions.[[110]](https://en.wikipedia.org/wiki/Cobalt#cite_note-110) In humans, B12 has two types of [alkyl](https://en.wikipedia.org/wiki/Alkane) [ligand](https://en.wikipedia.org/wiki/Ligand): [methyl](https://en.wikipedia.org/wiki/Methyl_group) and adenosyl. [MeB12](https://en.wikipedia.org/wiki/Methylcobalamin) promotes methyl (−CH3) group transfers. The adenosyl version of B12 catalyzes rearrangements in which a hydrogen atom is directly transferred between two adjacent atoms with concomitant exchange of the second substituent, X, which may be a carbon atom with substituents, an oxygen atom of an alcohol, or an amine. [Methylmalonyl coenzyme A mutase](https://en.wikipedia.org/wiki/Methylmalonyl_coenzyme_A_mutase) (MUT) converts [MMl-CoA](https://en.wikipedia.org/wiki/L-methylmalonyl-CoA) to [Su-CoA](https://en.wikipedia.org/wiki/Succinyl-CoA), an important step in the extraction of energy from proteins and fats.[[111]](https://en.wikipedia.org/wiki/Cobalt#cite_note-111)

Although far less common than other [metalloproteins](https://en.wikipedia.org/wiki/Metalloprotein) (e.g. those of zinc and iron), other cobaltoproteins are known besides B12. These proteins include [methionine aminopeptidase 2](https://en.wikipedia.org/wiki/METAP2), an enzyme that occurs in humans and other mammals that does not use the corrin ring of B12, but binds cobalt directly. Another non-corrin cobalt enzyme is [nitrile hydratase](https://en.wikipedia.org/wiki/Nitrile_hydratase), an enzyme in bacteria that metabolizes [nitriles](https://en.wikipedia.org/wiki/Nitrile).[[112]](https://en.wikipedia.org/wiki/Cobalt#cite_note-112)

**Precautions**

Main article: [Cobalt poisoning](https://en.wikipedia.org/wiki/Cobalt_poisoning)

|  |  |
| --- | --- |
| Cobalt | |
| **Hazards** | |
| [GHS pictograms](https://en.wikipedia.org/wiki/GHS_hazard_pictograms) | [The health hazard pictogram in the Globally Harmonized System of Classification and Labelling of Chemicals (GHS)](https://en.wikipedia.org/wiki/File:GHS-pictogram-silhouette.svg) |
| [GHS signal word](https://en.wikipedia.org/wiki/Globally_Harmonized_System_of_Classification_and_Labelling_of_Chemicals) | Danger |
| [GHS hazard statements](https://en.wikipedia.org/wiki/GHS_hazard_statement) | H317, H334, H413 |
| [GHS precautionary statements](https://en.wikipedia.org/wiki/GHS_precautionary_statements) | P261, P280, P342+311[[113]](https://en.wikipedia.org/wiki/Cobalt#cite_note-113) |
| [NFPA 704](https://en.wikipedia.org/wiki/NFPA_704) | NFPA 704 four-colored diamond  [0](https://en.wikipedia.org/wiki/NFPA_704#Red)  [2](https://en.wikipedia.org/wiki/NFPA_704#Blue)  [0](https://en.wikipedia.org/wiki/NFPA_704#Yellow) |

Cobalt is an essential element for life in minute amounts. The [LD50](https://en.wikipedia.org/wiki/Median_lethal_dose) value for soluble cobalt salts has been estimated to be between 150 and 500 mg/kg.[[114]](https://en.wikipedia.org/wiki/Cobalt#cite_note-Ullmann-114) In the US, the [Occupational Safety and Health Administration](https://en.wikipedia.org/wiki/Occupational_Safety_and_Health_Administration) (OSHA) has designated a [permissible exposure limit](https://en.wikipedia.org/wiki/Permissible_exposure_limit) (PEL) in the workplace as a time-weighted average (TWA) of 0.1 mg/m3. The [National Institute for Occupational Safety and Health](https://en.wikipedia.org/wiki/National_Institute_for_Occupational_Safety_and_Health) (NIOSH) has set a [recommended exposure limit](https://en.wikipedia.org/wiki/Recommended_exposure_limit) (REL) of 0.05 mg/m3, time-weighted average. The [IDLH](https://en.wikipedia.org/wiki/IDLH) (immediately dangerous to life and health) value is 20 mg/m3.[[115]](https://en.wikipedia.org/wiki/Cobalt#cite_note-115)

However, chronic cobalt ingestion has caused serious health problems at doses far less than the lethal dose. In 1966, the addition of cobalt compounds to stabilize [beer foam](https://en.wikipedia.org/wiki/Beer_foam) in Canada led to a peculiar form of toxin-induced [cardiomyopathy](https://en.wikipedia.org/wiki/Cardiomyopathy), which came to be known as *beer drinker's cardiomyopathy*.[[116]](https://en.wikipedia.org/wiki/Cobalt#cite_note-116)[[117]](https://en.wikipedia.org/wiki/Cobalt#cite_note-117)

It causes respiratory problems when inhaled.[[118]](https://en.wikipedia.org/wiki/Cobalt#cite_note-118) It also causes skin problems when touched; after [nickel](https://en.wikipedia.org/wiki/Nickel) and chromium, cobalt is a major cause of [contact dermatitis](https://en.wikipedia.org/wiki/Allergic_contact_dermatitis).[[119]](https://en.wikipedia.org/wiki/Cobalt#cite_note-119) These risks are faced by cobalt miners.

Cobalt can be effectively absorbed by charred pigs' bones; however, this process is inhibited by copper and zinc, which have greater affinities to bone char.[[120]](https://en.wikipedia.org/wiki/Cobalt#cite_note-120)

**See also**

* [Mining industry of the Democratic Republic of the Congo](https://en.wikipedia.org/wiki/Mining_industry_of_the_Democratic_Republic_of_the_Congo)
* [Coltan](https://en.wikipedia.org/wiki/Coltan)
* [Conflict mineral](https://en.wikipedia.org/wiki/Conflict_mineral)
* [Economy of the Democratic Republic of the Congo](https://en.wikipedia.org/wiki/Economy_of_the_Democratic_Republic_of_the_Congo)

**Further reading**

* *Harper, E. M.; Kavlak, G.; Graedel, T. E. (2012). "Tracking the metal of the goblins: Cobalt's cycle of use". Environmental Science & Technology.* ***46*** *(2): 1079–86.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1021/es201874e*](https://doi.org/10.1021%2Fes201874e)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*22142288*](https://www.ncbi.nlm.nih.gov/pubmed/22142288)*.*
* *Narendrula, R.; Nkongolo, K. K.; Beckett, P. (2012). "Comparative soil metal analyses in Sudbury (Ontario, Canada) and Lubumbashi (Katanga, DR-Congo)". Bulletin of Environmental Contamination and Toxicology.* ***88*** *(2): 187–92.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1007/s00128-011-0485-7*](https://doi.org/10.1007%2Fs00128-011-0485-7)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*22139330*](https://www.ncbi.nlm.nih.gov/pubmed/22139330)*.*
* *Pauwels, H.; Pettenati, M.; Greffié, C. (2010). "The combined effect of abandoned mines and agriculture on groundwater chemistry". Journal of Contaminant Hydrology.* ***115*** *(1–4): 64–78.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1016/j.jconhyd.2010.04.003*](https://doi.org/10.1016%2Fj.jconhyd.2010.04.003)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*20466452*](https://www.ncbi.nlm.nih.gov/pubmed/20466452)*.*
* *Bulut, G. (2006). "Recovery of copper and cobalt from ancient slag". Waste Management & Research : The Journal of the International Solid Wastes and Public Cleansing Association, Iswa.* ***24*** *(2): 118–24.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1177/0734242X06063350*](https://doi.org/10.1177%2F0734242X06063350)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*16634226*](https://www.ncbi.nlm.nih.gov/pubmed/16634226)*.*
* *Jefferson, J. A.; Escudero, E.; Hurtado, M. E.; Pando, J.; Tapia, R.; Swenson, E. R.; Prchal, J.; Schreiner, G. F.; Schoene, R. B.; Hurtado, A.; Johnson, R. J. (2002). "Excessive erythrocytosis, chronic mountain sickness, and serum cobalt levels". Lancet.* ***359*** *(9304): 407–8.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*11844517*](https://www.ncbi.nlm.nih.gov/pubmed/11844517)*.*
* *Løvold, T. V.; Haugsbø, L. (1999). "Cobalt mining factory--diagnoses 1822-32". Tidsskrift for den Norske Laegeforening : Tidsskrift for Praktisk Medicin, NY Raekke.* ***119*** *(30): 4544–6.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*10827501*](https://www.ncbi.nlm.nih.gov/pubmed/10827501)*.*
* *Bird, G. A.; Hesslein, R. H.; Mills, K. H.; Schwartz, W. J.; Turner, M. A. (1998). "Bioaccumulation of radionuclides in fertilized Canadian Shield lake basins". The Science of the Total Environment.* ***218*** *(1): 67–83.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*9718743*](https://www.ncbi.nlm.nih.gov/pubmed/9718743)*.*
* *Nemery, B. (1990). "Metal toxicity and the respiratory tract". The European Respiratory Journal.* ***3*** *(2): 202–19.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*2178966*](https://www.ncbi.nlm.nih.gov/pubmed/2178966)*.*
* *Kazantzis, G. (1981).* [*"Role of cobalt, iron, lead, manganese, mercury, platinum, selenium, and titanium in carcinogenesis"*](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1568837)*. Environmental Health Perspectives.* ***40****: 143–61.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1289/ehp.8140143*](https://doi.org/10.1289%2Fehp.8140143)*.* [*PMC*](https://en.wikipedia.org/wiki/PubMed_Central)[*1568837*](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1568837)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*7023929*](https://www.ncbi.nlm.nih.gov/pubmed/7023929)*.*
* *Kerfoot, E. J.; Fredrick, W. G.; Domeier, E. (1975). "Cobalt metal inhalation studies on miniature swine". American Industrial Hygiene Association Journal.* ***36*** *(1): 17–25.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1080/0002889758507202*](https://doi.org/10.1080%2F0002889758507202)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*1111264*](https://www.ncbi.nlm.nih.gov/pubmed/1111264)*.*

**References**

 [Oxford English Dictionary](https://en.wikipedia.org/wiki/Oxford_English_Dictionary), 2nd Edition 1989.

  *Meija, J.; et al. (2016).* [*"Atomic weights of the elements 2013 (IUPAC Technical Report)"*](https://www.degruyter.com/downloadpdf/j/pac.2016.88.issue-3/pac-2015-0305/pac-2015-0305.xml)*.* [*Pure and Applied Chemistry*](https://en.wikipedia.org/wiki/Pure_and_Applied_Chemistry)*.* ***88*** *(3): 265–91.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1515/pac-2015-0305*](https://doi.org/10.1515%2Fpac-2015-0305)*.*

  [*Greenwood, Norman N.*](https://en.wikipedia.org/wiki/Norman_Greenwood)*; Earnshaw, Alan (1997). Chemistry of the Elements (2nd ed.).* [*Butterworth-Heinemann*](https://en.wikipedia.org/wiki/Butterworth-Heinemann)*. pp. 1117–1119.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*0-08-037941-9*](https://en.wikipedia.org/wiki/Special:BookSources/0-08-037941-9)*.*

  *Danielle Bochove (November 1, 2017). "Electric car future spurs Cobalt rush: Swelling demand for product breathes new life into small Ontario town". Vancouver Sun. Bloomberg.*

  *Enghag, Per (2004). "Cobalt".* [*Encyclopedia of the elements: technical data, history, processing, applications*](https://books.google.com/books?id=aff7sEea39EC&pg=PA680)*. p. 667.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-3-527-30666-4*](https://en.wikipedia.org/wiki/Special:BookSources/978-3-527-30666-4)*.*

  *Murthy, V. S. R (2003). "Magnetic Properties of Materials".* [*Structure And Properties Of Engineering Materials*](https://books.google.com/books?id=fi_rnPJeTV8C&pg=PA381)*. p. 381.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-07-048287-6*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-07-048287-6)*.*

  *Celozzi, Salvatore; Araneo, Rodolfo; Lovat, Giampiero (2008-05-01).* [*Electromagnetic Shielding*](https://books.google.com/books?id=opQjaSj2yIMC&pg=PA27)*. p. 27.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-470-05536-6*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-470-05536-6)*.*

  *Lee, B.; Alsenz, R.; Ignatiev, A.; Van Hove, M.; Van Hove, M. A. (1978). "Surface structures of the two allotropic phases of cobalt". Physical Review B.* ***17*** *(4): 1510–1520.* [*Bibcode*](https://en.wikipedia.org/wiki/Bibcode)*:*[*1978PhRvB..17.1510L*](http://adsabs.harvard.edu/abs/1978PhRvB..17.1510L)*.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1103/PhysRevB.17.1510*](https://doi.org/10.1103%2FPhysRevB.17.1510)*.*

  [*"Properties and Facts for Cobalt"*](http://www.americanelements.com/co.html)*.* [*American Elements*](https://en.wikipedia.org/wiki/American_Elements)*. Retrieved 2008-09-19.*

  *Cobalt, Centre d'Information du Cobalt, Brussels (1966).* [*Cobalt*](https://books.google.com/books?id=H8XVAAAAMAAJ)*. p. 45.*

  *Holleman, A. F.; Wiberg, E.; Wiberg, N. (2007). "Cobalt". Lehrbuch der Anorganischen Chemie (in German) (102nd ed.). de Gruyter. pp. 1146–1152.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-3-11-017770-1*](https://en.wikipedia.org/wiki/Special:BookSources/978-3-11-017770-1)*.*

  *Housecroft, C. E.; Sharpe, A. G. (2008). Inorganic Chemistry (3rd ed.). Prentice Hall. p. 722.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0131755536*](https://en.wikipedia.org/wiki/Special:BookSources/978-0131755536)*.*

  *Rutley, Frank (2012-12-06).* [*Rutley’s Elements of Mineralogy*](https://books.google.com/books?id=7tfyCAAAQBAJ)*. Springer Science & Business Media. p. 40.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*9789401197694*](https://en.wikipedia.org/wiki/Special:BookSources/9789401197694)*.*

  *Krebs, Robert E. (2006). The history and use of our earth's chemical elements: a reference guide (2nd ed.). Greenwood Publishing Group. p. 107.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*0-313-33438-2*](https://en.wikipedia.org/wiki/Special:BookSources/0-313-33438-2)*.*

  *Petitto, Sarah C.; Marsh, Erin M.; Carson, Gregory A.; Langell, Marjorie A. (2008).* [*"Cobalt oxide surface chemistry: The interaction of CoO(100), Co3O4(110) and Co3O4(111) with oxygen and water"*](http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1021&context=chemistrylangell)*. Journal of Molecular Catalysis A: Chemical.* ***281****: 49–58.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1016/j.molcata.2007.08.023*](https://doi.org/10.1016%2Fj.molcata.2007.08.023)*.*

  [*Greenwood, Norman N.*](https://en.wikipedia.org/wiki/Norman_Greenwood)*; Earnshaw, Alan (1997). Chemistry of the Elements (2nd ed.).* [*Butterworth-Heinemann*](https://en.wikipedia.org/wiki/Butterworth-Heinemann)*. pp. 1119–1120.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*0-08-037941-9*](https://en.wikipedia.org/wiki/Special:BookSources/0-08-037941-9)*.*

  *Werner, A. (1912). "Zur Kenntnis des asymmetrischen Kobaltatoms. V".* [*Chemische Berichte*](https://en.wikipedia.org/wiki/Chemische_Berichte)*.* ***45****: 121–130.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1002/cber.19120450116*](https://doi.org/10.1002%2Fcber.19120450116)*.*

  *Gispert, Joan Ribas (2008). "Early Theories of Coordination Chemistry".* [*Coordination chemistry*](https://books.google.com/books?id=9d893122U6kC&pg=PR31)*. pp. 31–33.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-3-527-31802-5*](https://en.wikipedia.org/wiki/Special:BookSources/978-3-527-31802-5)*.*

  *James E. House (2008).* [*Inorganic chemistry*](https://books.google.com/books?id=ocKWuxOur-kC&pg=PA767)*. Academic Press. pp. 767–.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-12-356786-4*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-12-356786-4)*. Retrieved 2011-05-16.*

  *Charles M. Starks; Charles Leonard Liotta; Marc Halpern (1994).* [*Phase-transfer catalysis: fundamentals, applications, and industrial perspectives*](https://books.google.com/books?id=-QCGckdeKAkC&pg=PA600)*. Springer. pp. 600–.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-412-04071-9*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-412-04071-9)*. Retrieved 2011-05-16.*

  *Sigel, Astrid; Sigel, Helmut; Sigel, Roland, eds. (2010). Organometallics in Environment and Toxicology (Metal Ions in Life Sciences).* [*Cambridge*](https://en.wikipedia.org/wiki/Cambridge)*,* [*UK*](https://en.wikipedia.org/wiki/United_Kingdom)*:* [*Royal Society of Chemistry Publishing*](https://en.wikipedia.org/wiki/Royal_Society_of_Chemistry)*. p. 75.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-1-84755-177-1*](https://en.wikipedia.org/wiki/Special:BookSources/978-1-84755-177-1)*.*

  *Byrne, Erin K.; Richeson, Darrin S.; Theopold, Klaus H. (1986-01-01).* [*"Tetrakis(1-norbornyl)cobalt, a low spin tetrahedral complex of a first row transition metal"*](http://pubs.rsc.org/en/Content/ArticleLanding/1986/C3/c39860001491#!divAbstract)*. Journal of the Chemical Society, Chemical Communications.* ***0*** *(19): 1491.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1039/C39860001491*](https://doi.org/10.1039%2FC39860001491)*.* [*ISSN*](https://en.wikipedia.org/wiki/International_Standard_Serial_Number)[*0022-4936*](https://www.worldcat.org/issn/0022-4936)*.*

  *Byrne, Erin K.; Theopold, Klaus H. (1987-02-01). "Redox chemistry of tetrakis(1-norbornyl)cobalt. Synthesis and characterization of a cobalt(V) alkyl and self-exchange rate of a Co(III)/Co(IV) couple". Journal of the American Chemical Society.* ***109*** *(4): 1282–1283.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1021/ja00238a066*](https://doi.org/10.1021%2Fja00238a066)*.* [*ISSN*](https://en.wikipedia.org/wiki/International_Standard_Serial_Number)[*0002-7863*](https://www.worldcat.org/issn/0002-7863)*.*

  *Audi, G.; Bersillon, O.; Blachot, J.; Wapstra, A. H. (2003). "The NUBASE Evaluation of Nuclear and Decay Properties". Nuclear Physics A. Atomic Mass Data Center.* ***729****: 3–128.* [*Bibcode*](https://en.wikipedia.org/wiki/Bibcode)*:*[*2003NuPhA.729....3A*](http://adsabs.harvard.edu/abs/2003NuPhA.729....3A)*.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1016/j.nuclphysa.2003.11.001*](https://doi.org/10.1016%2Fj.nuclphysa.2003.11.001)*.*

  [Cobalt](http://www.britannica.com/EBchecked/topic/123235/cobalt-Co), Encyclopædia Britannica Online.

  *Pulak, Cemal (1998). "The Uluburun shipwreck: an overview". International Journal of Nautical Archaeology.* ***27*** *(3): 188–224.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1111/j.1095-9270.1998.tb00803.x*](https://doi.org/10.1111%2Fj.1095-9270.1998.tb00803.x)*.*

  *Henderson, Julian (2000). "Glass".* [*The Science and Archaeology of Materials: An Investigation of Inorganic Materials*](https://books.google.com/?id=p9xJ-VpUuNkC)*. Routledge. p. 60.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-415-19933-9*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-415-19933-9)*.*

  *Rehren, Th. (2003). "Aspects of the Production of Cobalt-blue Glass in Egypt". Archaeometry.* ***43*** *(4): 483–489.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1111/1475-4754.00031*](https://doi.org/10.1111%2F1475-4754.00031)*.*

  *Lucas, A. (2003).* [*Ancient Egyptian Materials and Industries*](https://books.google.com/?id=GugkliLHDMoC)*. Kessinger Publishing. p. 217.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-7661-5141-3*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-7661-5141-3)*.*

  *Dennis, W. H (2010). "Cobalt".* [*Metallurgy: 1863–1963*](https://books.google.com/books?id=UyE49SzKWHIC&pg=PA254)*. pp. 254–256.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-202-36361-5*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-202-36361-5)*.*

  Georg Brandt first showed cobalt to be a new metal in: G. Brandt (1735) "Dissertatio de semimetallis" (Dissertation on semi-metals), *Acta Literaria et Scientiarum Sveciae* (Journal of Swedish literature and sciences), vol. 4, pages 1–10.  
See also: **(1)** G. Brandt (1746) "Rön och anmärkningar angäende en synnerlig färg—cobolt" (Observations and remarks concerning an extraordinary pigment—cobalt), *Kongliga Svenska vetenskapsakademiens handlingar* (Transactions of the Royal Swedish Academy of Science), vol. 7, pp. 119–130; **(2)** G. Brandt (1748) "Cobalti nova species examinata et descripta" (Cobalt, a new element examined and described), *Acta Regiae Societatis Scientiarum Upsaliensis* (Journal of the Royal Scientific Society of Uppsala), 1st series, vol. 3, pp. 33–41; **(3)** James L. Marshall and Virginia R. Marshall (Spring 2003) ["Rediscovery of the Elements: Riddarhyttan, Sweden"](https://web.archive.org/web/20100703175508/http:/www.chem.unt.edu/Rediscovery/Riddarhyttan.pdf). *The Hexagon* (official journal of the [Alpha Chi Sigma](https://en.wikipedia.org/wiki/Alpha_Chi_Sigma) fraternity of chemists), vol. 94, no. 1, pages 3–8.

  *Wang, Shijie (2006). "Cobalt—Its recovery, recycling, and application". Journal of the Minerals, Metals and Materials Society.* ***58*** *(10): 47–50.* [*Bibcode*](https://en.wikipedia.org/wiki/Bibcode)*:*[*2006JOM....58j..47W*](http://adsabs.harvard.edu/abs/2006JOM....58j..47W)*.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1007/s11837-006-0201-y*](https://doi.org/10.1007%2Fs11837-006-0201-y)*.*

  [*Weeks, Mary Elvira*](https://en.wikipedia.org/wiki/Mary_Elvira_Weeks) *(1932). "The discovery of the elements. III. Some eighteenth-century metals". Journal of Chemical Education.* ***9****: 22.* [*Bibcode*](https://en.wikipedia.org/wiki/Bibcode)*:*[*1932JChEd...9...22W*](http://adsabs.harvard.edu/abs/1932JChEd...9...22W)*.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1021/ed009p22*](https://doi.org/10.1021%2Fed009p22)*.*

  *Ramberg, Ivar B. (2008).* [*The making of a land: geology of Norway*](https://books.google.com/books?id=rMVNE0F2SckC&pg=PA98)*. Geological Society. pp. 98–.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-82-92394-42-7*](https://en.wikipedia.org/wiki/Special:BookSources/978-82-92394-42-7)*. Retrieved 2011-04-30.*

  *Cyclopaedia (1852). C. Tomlinson. 9 divs, ed.* [*Cyclopædia of useful arts & manufactures*](https://books.google.com/books?id=w_cGAAAAQAAJ&pg=PA400)*. pp. 400–. Retrieved 2011-04-30.*

  *Wellmer, Friedrich-Wilhelm; Becker-Platen, Jens Dieter.* [*"Global Nonfuel Mineral Resources and Sustainability"*](http://pubs.usgs.gov/circ/2007/1294/paper1.html)*. United States Geological Survey.*

  *Westing, Arthur H; Stockholm International Peace Research Institute (1986). "cobalt".* [*Global resources and international conflict: environmental factors in strategic policy and action*](https://books.google.com/books?id=Xpypu9qqDncC&pg=PA75)*. pp. 75–78.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-19-829104-6*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-19-829104-6)*.*

  *Livingood, J.; Seaborg, Glenn T. (1938). "Long-Lived Radio Cobalt Isotopes". Physical Review.* ***53*** *(10): 847–848.* [*Bibcode*](https://en.wikipedia.org/wiki/Bibcode)*:*[*1938PhRv...53..847L*](http://adsabs.harvard.edu/abs/1938PhRv...53..847L)*.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1103/PhysRev.53.847*](https://doi.org/10.1103%2FPhysRev.53.847)*.*

  *Wu, C. S. (1957). "Experimental Test of Parity Conservation in Beta Decay". Physical Review.* ***105*** *(4): 1413–1415.* [*Bibcode*](https://en.wikipedia.org/wiki/Bibcode)*:*[*1957PhRv..105.1413W*](http://adsabs.harvard.edu/abs/1957PhRv..105.1413W)*.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1103/PhysRev.105.1413*](https://doi.org/10.1103%2FPhysRev.105.1413)*.*

  *Wróblewski, A. K. (2008).* [*"The Downfall of Parity – the Revolution That Happened Fifty Years Ago"*](https://pdfs.semanticscholar.org/c70d/c463a79d73a5cae734b0f53f1cd51da18628.pdf) *(PDF). Acta Physica Polonica B.* ***39*** *(2): 251.* [*Bibcode*](https://en.wikipedia.org/wiki/Bibcode)*:*[*2008AcPPB..39..251W*](http://adsabs.harvard.edu/abs/2008AcPPB..39..251W)*.*

  ["Richest Hole In The Mountain"](https://books.google.com/books?id=kNwDAAAAMBAJ&pg=PA65&dq=true#v=onepage&q=true&f=true) *Popular Mechanics*, May 1952, pp. 65–69.

  *Ptitsyn, D. A.; Chechetkin, V. M. (1980). "Creation of the Iron-Group Elements in a Supernova Explosion". Soviet Astronomy Letters.* ***6****: 61–64.* [*Bibcode*](https://en.wikipedia.org/wiki/Bibcode)*:*[*1980SvAL....6...61P*](http://adsabs.harvard.edu/abs/1980SvAL....6...61P)*.*

  *Nuccio, Pasquale Mario and Valenza, Mariano (1979).* [*"Determination of metallic iron, nickel and cobalt in meteorites"*](http://rruff.info/rdsmi/V35/RDSMI35_355.pdf) *(PDF). Rendiconti Societa Italiana di Mineralogia e Petrografia.* ***35*** *(1): 355–360.*

  *Kerr, Paul F. (1945).* [*"Cattierite and Vaesite: New Co-Ni Minerals from the Belgian Kongo"*](http://www.minsocam.org/ammin/AM30/AM30_483.pdf) *(PDF). American Mineralogist.* ***30****: 483–492.*

  *Buckley, A. N. (1987). "The Surface Oxidation of Cobaltite". Australian Journal of Chemistry.* ***40*** *(2): 231.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1071/CH9870231*](https://doi.org/10.1071%2FCH9870231)*.*

  *Young, R. (1957). "The geochemistry of cobalt". Geochimica et Cosmochimica Acta.* ***13****: 28–41.* [*Bibcode*](https://en.wikipedia.org/wiki/Bibcode)*:*[*1957GeCoA..13...28Y*](http://adsabs.harvard.edu/abs/1957GeCoA..13...28Y)*.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1016/0016-7037(57)90056-X*](https://doi.org/10.1016%2F0016-7037%2857%2990056-X)*.*

  *Talhout, Reinskje; Schulz, Thomas; Florek, Ewa; Van Benthem, Jan; Wester, Piet; Opperhuizen, Antoon (2011).* [*"Hazardous Compounds in Tobacco Smok"*](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3084482)*. International Journal of Environmental Research and Public Health.* ***8*** *(12): 613–628.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.3390/ijerph8020613*](https://doi.org/10.3390%2Fijerph8020613)*.* [*ISSN*](https://en.wikipedia.org/wiki/International_Standard_Serial_Number)[*1660-4601*](https://www.worldcat.org/issn/1660-4601)*.* [*PMC*](https://en.wikipedia.org/wiki/PubMed_Central)[*3084482*](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3084482)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*21556207*](https://www.ncbi.nlm.nih.gov/pubmed/21556207)*.*

  *Pourkhabbaz, A; Pourkhabbaz, H (2012).* [*"Investigation of Toxic Metals in the Tobacco of Different Iranian Cigarette Brands and Related Health Issues"*](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3586865)*. Iranian Journal of Basic Medical Sciences.* ***15*** *(1): 636–644.* [*PMC*](https://en.wikipedia.org/wiki/PubMed_Central)[*3586865*](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3586865)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*23493960*](https://www.ncbi.nlm.nih.gov/pubmed/23493960)*.*

  [*Cobalt Statistics and Information*](https://minerals.usgs.gov/minerals/pubs/commodity/cobalt/mcs-2018-cobal.pdf) *(PDF), U.S. Geological Survey, 2018*

  *Shedd, Kim B.* [*"Mineral Yearbook 2006: Cobalt"*](http://minerals.usgs.gov/minerals/pubs/commodity/cobalt/myb1-2006-cobal.pdf) *(PDF). United States Geological Survey. Retrieved 2008-10-26.*

  *Shedd, Kim B.* [*"Commodity Report 2008: Cobalt"*](http://minerals.usgs.gov/minerals/pubs/commodity/cobalt/mcs-2008-cobal.pdf) *(PDF). United States Geological Survey. Retrieved 2008-10-26.*

  *Henry Sanderson (March 14, 2017).* [*"Cobalt's meteoric rise at risk from Congo's Katanga"*](https://www.ft.com/content/bc8dc13c-07db-11e7-97d1-5e720a26771b)*. Financial Times.*

  *Davis, Joseph R. (2000).* [*ASM specialty handbook: nickel, cobalt, and their alloys*](https://books.google.com/?id=IePhmnbmRWkC&dq=cobalt+copper+nickel+ore+separate)*. ASM International. p. 347.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*0-87170-685-7*](https://en.wikipedia.org/wiki/Special:BookSources/0-87170-685-7)*.*

  [*"Cobalt"*](https://minerals.usgs.gov/minerals/pubs/commodity/cobalt/mcs-2016-cobal.pdf) *(PDF). United States Geological Survey, Mineral Commodity Summaries. January 2016. pp. 52–53.*

  *Thomas Wilson (October 26, 2017).* [*"We'll All Be Relying on Congo to Power Our Electric Cars"*](https://www.bloomberg.com/news/articles/2017-10-26/battery-boom-relies-on-one-african-nation-avoiding-chaos-of-past)*. Archived from* [*the original*](https://www.bloomberg.com/news/articles/2017-10-26/battery-boom-relies-on-one-african-nation-avoiding-chaos-of-past) *on March 1, 2018.*

  [*"African Mineral Production"*](http://www.bgs.ac.uk/mineralsuk/downloads/african_mp_01_05.pdf) *(PDF). British Geological Survey. Retrieved 2009-06-06.*

  *Frankel, Todd C. (2016-09-30).* [*"Cobalt mining for lithium ion batteries has a high human cost"*](https://www.washingtonpost.com/graphics/business/batteries/congo-cobalt-mining-for-lithium-ion-battery/)*.* [*Washington Post*](https://en.wikipedia.org/wiki/Washington_Post)*. Retrieved 2016-10-18.*

  *Mucha, Lena; Sadof, Karly Domb; Frankel, Todd C. (2018-02-28).* [*"Perspective - The hidden costs of cobalt mining"*](https://www.washingtonpost.com/news/in-sight/wp/2018/02/28/the-cost-of-cobalt/)*. Washington Post.* [*ISSN*](https://en.wikipedia.org/wiki/International_Standard_Serial_Number)[*0190-8286*](https://www.worldcat.org/issn/0190-8286)*. Retrieved 2018-03-07.*

  *Todd C. Frankel (September 30, 2016).* [*"THE COBALT PIPELINE: Tracing the path from deadly hand-dug mines in Congo to consumers' phones and laptops"*](https://www.washingtonpost.com/graphics/business/batteries/congo-cobalt-mining-for-lithium-ion-battery/)*. Washington Post.*

  Crawford, Alex. [Meet Dorsen, 8, who mines cobalt to make your smartphone work](http://news.sky.com/story/meet-dorsen-8-who-mines-cobalt-to-make-your-smartphone-work-10784120). *Sky News UK*. Retrieved on 2018-01-07.

  [Are you holding a product of child labour right now? (Video)](http://news.sky.com/video/are-you-holding-a-product-of-child-labour-right-now-10785338). *Sky News UK* (2017-02-28). Retrieved on 2018-01-07.

  [Child labour behind smart phone and electric car batteries](https://www.amnesty.org/en/latest/news/2016/01/child-labour-behind-smart-phone-and-electric-car-batteries/). *Amnesty International* (2016-01-19). Retrieved on 2018-01-07.

  Reisinger, Don. (2017-03-03) [Child Labor Revelation Prompts Apple to Make Supplier Policy Change](http://fortune.com/2017/03/03/apple-cobalt-child-labor/). *Fortune*. Retrieved on 2018-01-07.

  Frankel, Todd C. (2017-03-03) [Apple cracks down further on cobalt supplier in Congo as child labor persists](https://www.washingtonpost.com/news/the-switch/wp/2017/03/03/apple-cracks-down-further-on-cobalt-supplier-in-congo-as-child-labor-persists/). *The Washington Post*. Retrieved on 2018-01-07.

  *Wellmer, Friedrich-Wilhelm; Becker-Platen, Jens Dieter.* [*"Global Nonfuel Mineral Resources and Sustainability"*](http://pubs.usgs.gov/circ/2007/1294/paper1.html)*. Retrieved 2009-05-16.*

  [*"CAMEC – The Cobalt Champion"*](http://www.infomine.com/publications/docs/InternationalMining/Chadwick2008t.pdf) *(PDF). International Mining. July 2008. Retrieved 2011-11-18.*

  *Amy Witherden (6 July 2009).* [*"Daily podcast – July 6, 2009"*](http://www.miningweekly.com/article/daily-podcast---july-6-2009-2009-07-06-2)*. Mining weekly. Retrieved 2011-11-15.*

  [*Mining Journal*](https://www.mining-journal.com/capital-markets/news/1311386/-ivanhoe-pullback-investors-waiting) "The [Ivanhoe] pullback investors have been waiting for", Aspermont Ltd., London, UK, February 22, 2018. Retrieved November 21, 2018.

  [Shabalala, Zandi](https://www.reuters.com/article/us-congo-mining-cobalt/cobalt-to-be-declared-a-strategic-mineral-in-congo-idUSKCN1GQ2RX) "Cobalt to be declared a strategic mineral in Congo", Reuters, March 14, 2018. Retrieved October 3, 2018.]

  [Reuters](https://www.reuters.com/article/us-congo-mining/congos-kabila-signs-into-law-new-mining-code-idUSKCN1GL2MB) "Congo's Kabila signs into law new mining code", March 14, 2018. Retrieved October 3, 2018.]

  [The Canadian Ghost Town That Tesla Is Bringing Back to Life](https://www.bloomberg.com/news/features/2017-10-31/the-canadian-ghost-town-that-tesla-is-bringing-back-to-life). Bloomberg (2017-10-31). Retrieved on 2018-01-07.

  *Donachie, Matthew J. (2002).* [*Superalloys: A Technical Guide*](https://books.google.com/?id=vjCJ5pI1QpkC)*. ASM International.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-87170-749-9*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-87170-749-9)*.*

  *Campbell, Flake C (2008-06-30). "Cobalt and Cobalt Alloys".* [*Elements of metallurgy and engineering alloys*](https://books.google.com/books?id=6VdROgeQ5M8C&pg=PA557)*. pp. 557–558.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-87170-867-0*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-87170-867-0)*.*

  *Michel, R.; Nolte, M.; Reich M.; Löer, F. (1991). "Systemic effects of implanted prostheses made of cobalt-chromium alloys". Archives of Orthopaedic and Trauma Surgery.* ***110*** *(2): 61–74.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1007/BF00393876*](https://doi.org/10.1007%2FBF00393876)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*2015136*](https://www.ncbi.nlm.nih.gov/pubmed/2015136)*.*

  *Disegi, John A. (1999).* [*Cobalt-base Aloys for Biomedical Applications*](https://books.google.com/?id=z4rXM1EnPugC)*. ASTM International. p. 34.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*0-8031-2608-5*](https://en.wikipedia.org/wiki/Special:BookSources/0-8031-2608-5)*.*

  *Luborsky, F. E.; Mendelsohn, L. I.; Paine, T. O. (1957). "Reproducing the Properties of Alnico Permanent Magnet Alloys with Elongated Single-Domain Cobalt-Iron Particles". Journal of Applied Physics.* ***28*** *(344): 344.* [*Bibcode*](https://en.wikipedia.org/wiki/Bibcode)*:*[*1957JAP....28..344L*](http://adsabs.harvard.edu/abs/1957JAP....28..344L)*.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1063/1.1722744*](https://doi.org/10.1063%2F1.1722744)*.*

  *Biggs, T.; Taylor, S. S.; Van Der Lingen, E. (2005). "The Hardening of Platinum Alloys for Potential Jewellery Application". Platinum Metals Review.* ***49****: 2–15.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1595/147106705X24409*](https://doi.org/10.1595%2F147106705X24409)*.*

  *Hawkins, M. (2001). "Why we need cobalt". Applied Earth Science: Transactions of the Institution of Mining & Metallurgy, Section B.* ***110*** *(2): 66–71.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1179/aes.2001.110.2.66*](https://doi.org/10.1179%2Faes.2001.110.2.66)*.*

  *Armstrong, R. D.; Briggs, G. W. D.; Charles, E. A. (1988). "Some effects of the addition of cobalt to the nickel hydroxide electrode". Journal of Applied Electrochemistry.* ***18*** *(2): 215–219.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1007/BF01009266*](https://doi.org/10.1007%2FBF01009266)*.*

  *Zhang, P.; Yokoyama, Toshiro; Itabashi, Osamu; Wakui, Yoshito; Suzuki, Toshishige M.; Inoue, Katsutoshi (1999). "Recovery of metal values from spent nickel–metal hydride rechargeable batteries". Journal of Power Sources.* ***77*** *(2): 116–122.* [*Bibcode*](https://en.wikipedia.org/wiki/Bibcode)*:*[*1999JPS....77..116Z*](http://adsabs.harvard.edu/abs/1999JPS....77..116Z)*.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1016/S0378-7753(98)00182-7*](https://doi.org/10.1016%2FS0378-7753%2898%2900182-7)*.*

  [Carmakers' electric dreams depend on supplies of rare minerals](https://www.theguardian.com/environment/2017/jul/29/electric-cars-battery-manufacturing-cobalt-mining). *The Guardian* (2017-07-29). Retrieved on 2018-01-07.

  Castellano, Robert (2017-10-13) [How To Minimize Tesla's Cobalt Supply Chain Risk](https://seekingalpha.com/article/4113417-minimize-teslas-cobalt-supply-chain-risk). *Seeking Alpha*.

  [As Cobalt Supply Tightens, LiCo Energy Metals Announces Two New Cobalt Mines](https://cleantechnica.com/2017/11/28/cobalt-supply-tightens-lico-energy-metals-announces-two-new-cobalt-mines/). CleanTechnica (2017-11-28). Retrieved on 2018-01-07.

  Shilling, Erik (2017-10-31) [We May Not Have Enough Minerals To Even Meet Electric Car Demand](https://jalopnik.com/we-may-not-have-enough-minerals-to-even-meet-electric-c-1820008337). jalopnik.com

  Hermes, Jennifer. (2017-05-31) [Tesla & GE Face Major Shortage Of Ethically Sourced Cobalt](https://www.environmentalleader.com/2017/05/shortage-ethically-sourced-cobalt-congo-causes-trouble-ge-apple-tesla/). Environmentalleader.com. Retrieved on 2018-01-07.

  [Electric cars yet to turn cobalt market into gold mine – Nornickel](http://www.mining.com/web/electric-cars-yet-turn-cobalt-market-gold-mine-nornickel/). MINING.com (2017-10-30). Retrieved on 2018-01-07.

  *Khodakov, Andrei Y.; Chu, Wei & Fongarland, Pascal (2007). "Advances in the Development of Novel Cobalt Fischer-Tropsch Catalysts for Synthesis of Long-Chain Hydrocarbons and Clean Fuels". Chemical Reviews.* ***107*** *(5): 1692–1744.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1021/cr050972v*](https://doi.org/10.1021%2Fcr050972v)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*17488058*](https://www.ncbi.nlm.nih.gov/pubmed/17488058)*.*

  *Hebrard, Frédéric & Kalck, Philippe (2009). "Cobalt-Catalyzed Hydroformylation of Alkenes: Generation and Recycling of the Carbonyl Species, and Catalytic Cycle". Chemical Reviews.* ***109*** *(9): 4272–4282.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1021/cr8002533*](https://doi.org/10.1021%2Fcr8002533)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*19572688*](https://www.ncbi.nlm.nih.gov/pubmed/19572688)*.*

  *Overman, Frederick (1852).* [*A treatise on metallurgy*](https://books.google.com/?id=APgQAAAAIAAJ&pg=PA631)*. D. Appleton & company. pp. 631–637.*

  *Muhlethaler, Bruno; Thissen, Jean; Muhlethaler, Bruno (1969). "Smalt". Studies in Conservation.* ***14*** *(2): 47–61.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.2307/1505347*](https://doi.org/10.2307%2F1505347)*.* [*JSTOR*](https://en.wikipedia.org/wiki/JSTOR)[*1505347*](https://www.jstor.org/stable/1505347)*.*

  *Gehlen, A. F. (1803).* [*"Ueber die Bereitung einer blauen Farbe aus Kobalt, die eben so schön ist wie Ultramarin. Vom Bürger Thenard"*](https://books.google.com/?id=UGsMAQAAIAAJ&pg=RA1-PA506)*. Neues allgemeines Journal der Chemie, Band 2. H. Frölich.* (German translation from L. J. Thénard; Journal des Mines; Brumaire 12 1802; p 128–136)

  *Witteveen, H. J.; Farnau, E. F. (1921). "Colors Developed by Cobalt Oxides". Industrial & Engineering Chemistry.* ***13*** *(11): 1061–1066.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1021/ie50143a048*](https://doi.org/10.1021%2Fie50143a048)*.*

  *Venetskii, S. (1970). "The charge of the guns of peace". Metallurgist.* ***14*** *(5): 334–336.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1007/BF00739447*](https://doi.org/10.1007%2FBF00739447)*.*

  *Mandeville, C.; Fulbright, H. (1943).* [*"The Energies of the γ-Rays from Sb122, Cd115, Ir192, Mn54, Zn65, and Co60"*](https://journals.aps.org/pr/abstract/10.1103/PhysRev.64.265)*. Physical Review.* ***64*** *(9–10): 265–267.* [*Bibcode*](https://en.wikipedia.org/wiki/Bibcode)*:*[*1943PhRv...64..265M*](http://adsabs.harvard.edu/abs/1943PhRv...64..265M)*.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1103/PhysRev.64.265*](https://doi.org/10.1103%2FPhysRev.64.265)*.*

  *Wilkinson, V. M; Gould, G (1998).* [*Food irradiation: a reference guide*](https://books.google.com/books?id=FpIpsqs7CRUC&pg=PA53)*. p. 53.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-1-85573-359-6*](https://en.wikipedia.org/wiki/Special:BookSources/978-1-85573-359-6)*.*

  *Blakeslee, Sandra (1984-05-01).* [*"The Juarez accident"*](https://query.nytimes.com/gst/fullpage.html?sec=health&res=9501E7D71338F932A35756C0A962948260)*. New York Times. Retrieved 2009-06-06.*

  [*"Ciudad Juarez orphaned source dispersal, 1983"*](http://www.johnstonsarchive.net/nuclear/radevents/1983MEX1.html)*. Wm. Robert Johnston. 2005-11-23. Retrieved 2009-10-24.*

  *National Research Council (U.S.). Committee on Radiation Source Use and Replacement; National Research Council (U.S.). Nuclear and Radiation Studies Board (January 2008).* [*Radiation source use and replacement: abbreviated version*](https://books.google.com/books?id=3cT2REdXJ98C&pg=PA35)*. National Academies Press. pp. 35–.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-309-11014-3*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-309-11014-3)*. Retrieved 2011-04-29.*

  *Meyer, Theresa (2001-11-30).* [*Physical Therapist Examination Review*](https://books.google.com/books?id=-gfKqUBGNgoC&pg=PA368)*. p. 368.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-1-55642-588-2*](https://en.wikipedia.org/wiki/Special:BookSources/978-1-55642-588-2)*.*

  *Kalnicky, D.; Singhvi, R. (2001). "Field portable XRF analysis of environmental samples". Journal of Hazardous Materials.* ***83*** *(1–2): 93–122.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1016/S0304-3894(00)00330-7*](https://doi.org/10.1016%2FS0304-3894%2800%2900330-7)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*11267748*](https://www.ncbi.nlm.nih.gov/pubmed/11267748)*.*

  *Payne, L. R. (1977). "The Hazards of Cobalt". Occupational Medicine.* ***27*** *(1): 20–25.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1093/occmed/27.1.20*](https://doi.org/10.1093%2Foccmed%2F27.1.20)*.*

  *Davis, Joseph R; Handbook Committee, ASM International (2000-05-01). "Cobalt".* [*Nickel, cobalt, and their alloys*](https://books.google.com/books?id=IePhmnbmRWkC&pg=PA354)*. p. 354.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-87170-685-0*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-87170-685-0)*.*

  *Committee On Technological Alternatives For Cobalt Conservation, National Research Council (U.S.); National Materials Advisory Board, National Research Council (U.S.) (1983). "Ground–Coat Frit".* [*Cobalt conservation through technological alternatives*](https://books.google.com/books?id=-CIrAAAAYAAJ&pg=PA129)*. p. 129.*

  *Yamada, Kazuhiro (2013). "Chapter 9. Cobalt: Its Role in Health and Disease". In Astrid Sigel; Helmut Sigel; Roland K. O. Sigel. Interrelations between Essential Metal Ions and Human Diseases. Metal Ions in Life Sciences.* ***13****. Springer. pp. 295–320.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1007/978-94-007-7500-8\_9*](https://doi.org/10.1007%2F978-94-007-7500-8_9)*.*

  *Cracan, Valentin; Banerjee, Ruma (2013). "Chapter 10 Cobalt and Corrinoid Transport and Biochemistry". In Banci, Lucia. Metallomics and the Cell. Metal Ions in Life Sciences.* ***12****. Springer.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1007/978-94-007-5561-10\_10*](https://doi.org/10.1007%2F978-94-007-5561-10_10)*.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-94-007-5560-4*](https://en.wikipedia.org/wiki/Special:BookSources/978-94-007-5560-4)*.* electronic-book [ISBN](https://en.wikipedia.org/wiki/International_Standard_Book_Number) [978-94-007-5561-1](https://en.wikipedia.org/wiki/Special:BookSources/978-94-007-5561-1) [ISSN](https://en.wikipedia.org/wiki/International_Standard_Serial_Number) [1559-0836](https://www.worldcat.org/search?fq=x0:jrnl&q=n2:1559-0836) electronic-[ISSN](https://en.wikipedia.org/wiki/International_Standard_Serial_Number) [1868-0402](https://www.worldcat.org/search?fq=x0:jrnl&q=n2:1868-0402).

  *Schwarz, F. J.; Kirchgessner, M.; Stangl, G. I. (2000). "Cobalt requirement of beef cattle – feed intake and growth at different levels of cobalt supply". Journal of Animal Physiology and Animal Nutrition.* ***83*** *(3): 121–131.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1046/j.1439-0396.2000.00258.x*](https://doi.org/10.1046%2Fj.1439-0396.2000.00258.x)*.*

  [*"Soils"*](http://sci.waikato.ac.nz/farm/content/soils.html#bush_sickness)*. Waikato University. Retrieved 2012-01-16.*

  *McDowell, Lee Russell (2008).* [*Vitamins in Animal and Human Nutrition*](https://books.google.com/books?id=UR9MnQ806LsC&pg=PA525) *(2nd ed.). Hoboken: John Wiley & Sons. p. 525.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*9780470376683*](https://en.wikipedia.org/wiki/Special:BookSources/9780470376683)*.*

  [Australian Academy of Science > Deceased Fellows > Hedley Ralph Marston 1900–1965](http://www.asap.unimelb.edu.au/bsparcs/aasmemoirs/marston.htm) Accessed 12 May 2013.

  *Voet, Judith G.; Voet, Donald (1995). Biochemistry. New York: J. Wiley & Sons. p. 675.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*0-471-58651-X*](https://en.wikipedia.org/wiki/Special:BookSources/0-471-58651-X)*.* [*OCLC*](https://en.wikipedia.org/wiki/OCLC)[*31819701*](https://www.worldcat.org/oclc/31819701)*.*

  *Smith, David M.; Golding, Bernard T.; Radom, Leo (1999). "Understanding the Mechanism of B12-Dependent Methylmalonyl-CoA Mutase: Partial Proton Transfer in Action". Journal of the American Chemical Society.* ***121*** *(40): 9388–9399.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1021/ja991649a*](https://doi.org/10.1021%2Fja991649a)*.*

  *Kobayashi, Michihiko; Shimizu, Sakayu (1999). "Cobalt proteins". European Journal of Biochemistry.* ***261*** *(1): 1–9.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1046/j.1432-1327.1999.00186.x*](https://doi.org/10.1046%2Fj.1432-1327.1999.00186.x)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*10103026*](https://www.ncbi.nlm.nih.gov/pubmed/10103026)*.*

  <https://www.sigmaaldrich.com/catalog/product/aldrich/356891?lang=en&region=US>

  Donaldson, John D. and Beyersmann, Detmar (2005) "Cobalt and Cobalt Compounds" in *Ullmann's Encyclopedia of Industrial Chemistry*, Wiley-VCH, Weinheim. [doi](https://en.wikipedia.org/wiki/Digital_object_identifier):[10.1002/14356007.a07\_281.pub2](https://doi.org/10.1002%2F14356007.a07_281.pub2)

  [*"NIOSH Pocket Guide to Chemical Hazards #0146"*](https://www.cdc.gov/niosh/npg/npgd0146.html)*.* [*National Institute for Occupational Safety and Health*](https://en.wikipedia.org/wiki/National_Institute_for_Occupational_Safety_and_Health) *(NIOSH).*

  *Morin Y; Tětu A; Mercier G (1969). "Quebec beer-drinkers' cardiomyopathy: Clinical and hemodynamic aspects". Annals of the New York Academy of Sciences.* ***156*** *(1): 566–576.* [*Bibcode*](https://en.wikipedia.org/wiki/Bibcode)*:*[*1969NYASA.156..566M*](http://adsabs.harvard.edu/abs/1969NYASA.156..566M)*.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1111/j.1749-6632.1969.tb16751.x*](https://doi.org/10.1111%2Fj.1749-6632.1969.tb16751.x)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*5291148*](https://www.ncbi.nlm.nih.gov/pubmed/5291148)*.*

  *Barceloux, Donald G. & Barceloux, Donald (1999). "Cobalt". Clinical Toxicology.* ***37*** *(2): 201–216.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1081/CLT-100102420*](https://doi.org/10.1081%2FCLT-100102420)*.*

  *Elbagir, Nima; van Heerden, Dominique; Mackintosh, Eliza (May 2018).* [*"Dirty Energy"*](http://edition.cnn.com/interactive/2018/05/africa/congo-cobalt-dirty-energy-intl/)*. CNN. Retrieved 30 May 2018.*

  *Basketter, David A.; Angelini, Gianni; Ingber, Arieh; Kern, Petra S.; Menné, Torkil (2003). "Nickel, chromium and cobalt in consumer products: revisiting safe levels in the new millennium". Contact Dermatitis.* ***49*** *(1): 1–7.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1111/j.0105-1873.2003.00149.x*](https://doi.org/10.1111%2Fj.0105-1873.2003.00149.x)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*14641113*](https://www.ncbi.nlm.nih.gov/pubmed/14641113)*.*

* 1.  *Xiangliang, Pan; Jianlong, Wang; Daoyong, Zhang (January 2009). "Sorption of cobalt to bone char: Kinetics, competitive sorption and mechanism". Salination.* ***249*** *(2): 609–614.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1016/j.desal.2009.01.027*](https://doi.org/10.1016%2Fj.desal.2009.01.027)*.*

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