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**Cadmium**

From Wikipedia, the free encyclopedia

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

For the album by Sky, see [Cadmium (album)](https://en.wikipedia.org/wiki/Cadmium_(album)).

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| --- | --- |
| Cadmium,  48Cd | |
| [Cadmium-crystal bar.jpg](https://en.wikipedia.org/wiki/File:Cadmium-crystal_bar.jpg) | |
| **General properties** | |
| **Pronunciation** | [/ˈkædmiəm/](https://en.wikipedia.org/wiki/Help:IPA/English) ​([*KAD-mee-əm*](https://en.wikipedia.org/wiki/Help:Pronunciation_respelling_key)) |
| **Appearance** | silvery bluish-gray metallic |
| [**Standard atomic weight**](https://en.wikipedia.org/wiki/Standard_atomic_weight) **(*A*r, standard)** | 112.414(4)[[1]](https://en.wikipedia.org/wiki/Cadmium#cite_note-CIAAW2016-1) |
| **Cadmium 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](https://en.wikipedia.org/wiki/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 | [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) | | [Zn](https://en.wikipedia.org/wiki/Zinc) ↑ **Cd** ↓ [Hg](https://en.wikipedia.org/wiki/Mercury_(element)) | | [silver](https://en.wikipedia.org/wiki/Silver) ← **cadmium** → [indium](https://en.wikipedia.org/wiki/Indium) | | | | |
| [**Atomic number**](https://en.wikipedia.org/wiki/Atomic_number)(*Z*) | 48 |
| [**Group**](https://en.wikipedia.org/wiki/Group_(periodic_table)) | [group 12](https://en.wikipedia.org/wiki/Group_12_element) |
| [**Period**](https://en.wikipedia.org/wiki/Period_(periodic_table)) | [period 5](https://en.wikipedia.org/wiki/Period_(periodic_table)#Period_5) |
| [**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) | [post-transition metal](https://en.wikipedia.org/wiki/Post-transition_metal), alternatively considered a [transition metal](https://en.wikipedia.org/wiki/Transition_metal) |
| [**Electron configuration**](https://en.wikipedia.org/wiki/Electron_configuration) | [[Kr](https://en.wikipedia.org/wiki/Krypton)] 4d10 5s2 |
| Electrons per shell | 2, 8, 18, 18, 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) | 594.22 [K](https://en.wikipedia.org/wiki/Kelvin) ​(321.07 °C, ​609.93 °F) |
| [**Boiling point**](https://en.wikipedia.org/wiki/Boiling_point) | 1040 K ​(767 °C, ​1413 °F) |
| [**Density**](https://en.wikipedia.org/wiki/Density)(near r.t.) | 8.65 g/cm3 |
| when liquid (at m.p.) | 7.996 g/cm3 |
| [**Heat of fusion**](https://en.wikipedia.org/wiki/Enthalpy_of_fusion) | 6.21 [kJ/mol](https://en.wikipedia.org/wiki/Kilojoule_per_mole) |
| [**Heat of vaporization**](https://en.wikipedia.org/wiki/Enthalpy_of_vaporization) | 99.87 kJ/mol |
| [**Molar heat capacity**](https://en.wikipedia.org/wiki/Molar_heat_capacity) | 26.020 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) | 530 | 583 | 654 | 745 | 867 | 1040 | | |
| **Atomic properties** | |
| [**Oxidation states**](https://en.wikipedia.org/wiki/Oxidation_state) | −2, +1, **+2** (a mildly [basic](https://en.wikipedia.org/wiki/Base_(chemistry)) oxide) |
| [**Electronegativity**](https://en.wikipedia.org/wiki/Electronegativity) | Pauling scale: 1.69 |
| [**Ionization energies**](https://en.wikipedia.org/wiki/Ionization_energy) | * 1st: 867.8 kJ/mol * 2nd: 1631.4 kJ/mol * 3rd: 3616 kJ/mol |
| [**Atomic radius**](https://en.wikipedia.org/wiki/Atomic_radius) | empirical: 151 [pm](https://en.wikipedia.org/wiki/Picometre) |
| [**Covalent radius**](https://en.wikipedia.org/wiki/Covalent_radius) | 144±9 pm |
| [**Van der Waals radius**](https://en.wikipedia.org/wiki/Van_der_Waals_radius) | 158 pm |
| [Color lines in a spectral range](https://en.wikipedia.org/wiki/File:Cadmium_spectrum_visible.png)  [**Spectral lines**](https://en.wikipedia.org/wiki/Spectral_line) **of cadmium** | |
| **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 cadmium](https://en.wikipedia.org/wiki/File:Hexagonal_close_packed.svg) |
| [**Speed of sound**](https://en.wikipedia.org/wiki/Speed_of_sound)thin rod | 2310 m/s (at 20 °C) |
| [**Thermal expansion**](https://en.wikipedia.org/wiki/Coefficient_of_thermal_expansion) | 30.8 µm/(m·K) (at 25 °C) |
| [**Thermal conductivity**](https://en.wikipedia.org/wiki/Thermal_conductivity) | 96.6 W/(m·K) |
| [**Electrical resistivity**](https://en.wikipedia.org/wiki/Electrical_resistivity_and_conductivity) | 72.7 nΩ·m (at 22 °C) |
| [**Magnetic ordering**](https://en.wikipedia.org/wiki/Magnetism) | [diamagnetic](https://en.wikipedia.org/wiki/Diamagnetic)[[2]](https://en.wikipedia.org/wiki/Cadmium#cite_note-2) |
| [**Magnetic susceptibility**](https://en.wikipedia.org/wiki/Magnetic_susceptibility) | −19.8·10−6 cm3/mol[[3]](https://en.wikipedia.org/wiki/Cadmium#cite_note-3) |
| [**Young's modulus**](https://en.wikipedia.org/wiki/Young%27s_modulus) | 50 GPa |
| [**Shear modulus**](https://en.wikipedia.org/wiki/Shear_modulus) | 19 GPa |
| [**Bulk modulus**](https://en.wikipedia.org/wiki/Bulk_modulus) | 42 GPa |
| [**Poisson ratio**](https://en.wikipedia.org/wiki/Poisson%27s_ratio) | 0.30 |
| [**Mohs hardness**](https://en.wikipedia.org/wiki/Mohs_scale_of_mineral_hardness) | 2.0 |
| [**Brinell hardness**](https://en.wikipedia.org/wiki/Brinell_hardness_test) | 203–220 MPa |
| [**CAS Number**](https://en.wikipedia.org/wiki/CAS_Registry_Number) | 7440-43-9 |
| **History** | |
| [**Discovery**](https://en.wikipedia.org/wiki/Timeline_of_chemical_element_discoveries) **and first isolation** | [Karl Samuel Leberecht Hermann](https://en.wikipedia.org/wiki/Karl_Samuel_Leberecht_Hermann) and [Friedrich Stromeyer](https://en.wikipedia.org/wiki/Friedrich_Stromeyer) (1817) |
| **Named by** | Friedrich Stromeyer (1817) |
| **Main** [**isotopes of cadmium**](https://en.wikipedia.org/wiki/Isotopes_of_cadmium) | |
| |  |  |  |  |  | | --- | --- | --- | --- | --- | | [**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) | | **106Cd** | 1.25% | [stable](https://en.wikipedia.org/wiki/Stable_isotope) | | | | **107Cd** | [syn](https://en.wikipedia.org/wiki/Synthetic_radioisotope) | 6.5 h | [ε](https://en.wikipedia.org/wiki/Electron_capture) | [107Ag](https://en.wikipedia.org/wiki/Silver-107) | | **108Cd** | 0.89% | stable | | | | **109Cd** | syn | 462.6 d | ε | [109Ag](https://en.wikipedia.org/wiki/Silver-109) | | **110Cd** | 12.47% | stable | | | | **111Cd** | 12.80% | stable | | | | **112Cd** | 24.11% | stable | | | | **113Cd** | 12.23% | 7.7×1015 y | [β−](https://en.wikipedia.org/wiki/Beta_decay) | [113In](https://en.wikipedia.org/wiki/Indium-113) | | **113**[**m**](https://en.wikipedia.org/wiki/Nuclear_isomer)**Cd** | syn | 14.1 y | β− | 113In | | [IT](https://en.wikipedia.org/wiki/Isomeric_transition) | [113Cd](https://en.wikipedia.org/wiki/Cadmium-113) | | **114Cd** | 28.75% | stable | | | | **115Cd** | syn | 53.46 h | β− | [115In](https://en.wikipedia.org/wiki/Indium-115) | | **116Cd** | 7.51% | 3.1×1019 y | β−β− | [116Sn](https://en.wikipedia.org/wiki/Tin-116) | | |
| * [view](https://en.wikipedia.org/wiki/Template:Infobox_cadmium) * [talk](https://en.wikipedia.org/wiki/Template_talk:Infobox_cadmium) * [edit](https://en.wikipedia.org/w/index.php?title=Template:Infobox_cadmium&action=edit)   | [references](https://en.wikipedia.org/wiki/List_of_data_references_for_chemical_elements) | |

**Cadmium** is a [chemical element](https://en.wikipedia.org/wiki/Chemical_element) with symbol **Cd** and [atomic number](https://en.wikipedia.org/wiki/Atomic_number) 48. This soft, bluish-white metal is chemically similar to the two other stable metals in [group 12](https://en.wikipedia.org/wiki/Group_12_element), [zinc](https://en.wikipedia.org/wiki/Zinc) and [mercury](https://en.wikipedia.org/wiki/Mercury_(element)). Like zinc, it demonstrates [oxidation state](https://en.wikipedia.org/wiki/Oxidation_state) +2 in most of its compounds, and like mercury, it has a lower melting point than the [transition metals](https://en.wikipedia.org/wiki/Transition_metal) in [groups 3](https://en.wikipedia.org/wiki/Group_3_element) through [11](https://en.wikipedia.org/wiki/Group_11_element). Cadmium and its [congeners](https://en.wikipedia.org/wiki/Congener_(chemistry)) in group 12 are often not considered transition metals, in that they do not have partly filled *d* or *f* electron shells in the elemental or common oxidation states. The average concentration of cadmium in Earth's crust is between 0.1 and 0.5 parts per million (ppm). It was discovered in 1817 simultaneously by [Stromeyer](https://en.wikipedia.org/wiki/Friedrich_Stromeyer) and [Hermann](https://en.wikipedia.org/wiki/Karl_Samuel_Leberecht_Hermann), both in Germany, as an impurity in [zinc carbonate](https://en.wikipedia.org/wiki/Zinc_carbonate).

Cadmium occurs as a minor component in most zinc ores and is a byproduct of zinc production. Cadmium was used for a long time as a corrosion-resistant plating on [steel](https://en.wikipedia.org/wiki/Steel), and cadmium compounds are used as red, orange and yellow [pigments](https://en.wikipedia.org/wiki/Cadmium_pigments), to color [glass](https://en.wikipedia.org/wiki/Colored_glass), and to stabilize [plastic](https://en.wikipedia.org/wiki/Plastic). Cadmium use is generally decreasing because it is [toxic](https://en.wikipedia.org/wiki/Toxicity) (it is specifically listed in the European [Restriction of Hazardous Substances](https://en.wikipedia.org/wiki/ROHS)[[4]](https://en.wikipedia.org/wiki/Cadmium#cite_note-ReferenceA-4)) and [nickel-cadmium batteries](https://en.wikipedia.org/wiki/Nickel-cadmium_battery) have been replaced with [nickel-metal hydride](https://en.wikipedia.org/wiki/Nickel-metal_hydride_battery) and [lithium-ion](https://en.wikipedia.org/wiki/Lithium-ion_battery) batteries. One of its few new uses is [cadmium telluride](https://en.wikipedia.org/wiki/Cadmium_telluride) [solar panels](https://en.wikipedia.org/wiki/Solar_panel).

Although cadmium has no known biological function in higher organisms, a cadmium-dependent [carbonic anhydrase](https://en.wikipedia.org/wiki/Carbonic_anhydrase) has been found in marine [diatoms](https://en.wikipedia.org/wiki/Diatom).



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* [9 See also](https://en.wikipedia.org/wiki/Cadmium#See_also)
* [10 References](https://en.wikipedia.org/wiki/Cadmium#References)
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**Characteristics**

**Physical properties**

Cadmium is a soft, [malleable](https://en.wikipedia.org/wiki/Malleable), [ductile](https://en.wikipedia.org/wiki/Ductility), bluish-white [divalent](https://en.wikipedia.org/wiki/Divalent) [metal](https://en.wikipedia.org/wiki/Metal). It is similar in many respects to zinc but forms [complex](https://en.wikipedia.org/wiki/Complex_(chemistry)) compounds.[[5]](https://en.wikipedia.org/wiki/Cadmium#cite_note-Holl-5) Unlike most other metals, cadmium is resistant to [corrosion](https://en.wikipedia.org/wiki/Corrosion) and is used as a protective [plate](https://en.wikipedia.org/wiki/Plating) on other metals. As a bulk metal, cadmium is [insoluble](https://en.wikipedia.org/wiki/Insoluble) in water and is not [flammable](https://en.wikipedia.org/wiki/Flammability); however, in its powdered form it may burn and release [toxic fumes](https://en.wikipedia.org/wiki/Cadmium_oxide).[[6]](https://en.wikipedia.org/wiki/Cadmium#cite_note-ATSDR-6)

**Chemical properties**

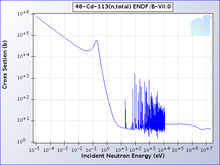
See also: [Category:Cadmium compounds](https://en.wikipedia.org/wiki/Category:Cadmium_compounds).

Although cadmium usually has an [oxidation state](https://en.wikipedia.org/wiki/Oxidation_state) of +2, it also exists in the +1 state. Cadmium and its [congeners](https://en.wikipedia.org/wiki/Congener_(chemistry)) are not always considered transition metals, in that they do not have partly filled d or f electron shells in the elemental or common oxidation states.[[7]](https://en.wikipedia.org/wiki/Cadmium#cite_note-7) Cadmium burns in air to form brown amorphous [cadmium oxide](https://en.wikipedia.org/wiki/Cadmium_oxide) (CdO); the [crystalline](https://en.wikipedia.org/wiki/Crystal) form of this compound is a dark red which changes color when heated, similar to [zinc oxide](https://en.wikipedia.org/wiki/Zinc_oxide). [Hydrochloric acid](https://en.wikipedia.org/wiki/Hydrochloric_acid), [sulfuric acid](https://en.wikipedia.org/wiki/Sulfuric_acid), and [nitric acid](https://en.wikipedia.org/wiki/Nitric_acid) dissolve cadmium by forming [cadmium chloride](https://en.wikipedia.org/wiki/Cadmium_chloride) (CdCl2), [cadmium sulfate](https://en.wikipedia.org/wiki/Cadmium_sulfate) (CdSO4), or [cadmium nitrate](https://en.wikipedia.org/wiki/Cadmium_nitrate) (Cd(NO3)2). The oxidation state +1 can be produced by dissolving cadmium in a mixture of cadmium chloride and [aluminium chloride](https://en.wikipedia.org/wiki/Aluminium_chloride), forming the Cd22+ cation, which is similar to the Hg22+ cation in [mercury(I) chloride](https://en.wikipedia.org/wiki/Mercury(I)_chloride).[[5]](https://en.wikipedia.org/wiki/Cadmium#cite_note-Holl-5)

Cd + CdCl2 + 2 AlCl3 → Cd2(AlCl4)2

The structures of many cadmium complexes with [nucleobases](https://en.wikipedia.org/wiki/Nucleobase), [amino acids](https://en.wikipedia.org/wiki/Amino_acid), and [vitamins](https://en.wikipedia.org/wiki/Vitamin) have been determined.[[8]](https://en.wikipedia.org/wiki/Cadmium#cite_note-8)

**Isotopes**

[](https://en.wikipedia.org/wiki/File:Cadmium_cutoff.png)

The cadmium-113 total cross section clearly showing the cadmium cut-off

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

Naturally occurring cadmium is composed of 8 [isotopes](https://en.wikipedia.org/wiki/Isotope). Two of them are [radioactive](https://en.wikipedia.org/wiki/Radionuclide), and three are expected to [decay](https://en.wikipedia.org/wiki/Radioactive_decay) but have not done so under laboratory conditions. The two natural radioactive isotopes are 113Cd ([beta decay](https://en.wikipedia.org/wiki/Beta_decay), half-life is 7.7 × 1015 years) and 116Cd (two-neutrino [double beta decay](https://en.wikipedia.org/wiki/Double_beta_decay), half-life is 2.9 × 1019 years). The other three are 106Cd, 108Cd (both [double electron capture](https://en.wikipedia.org/wiki/Double_electron_capture)), and 114Cd (double beta decay); only lower limits on these half-lives have been determined. At least three isotopes – 110Cd, 111Cd, and 112Cd – are stable. Among the isotopes that do not occur naturally, the most long-lived are 109Cd with a half-life of 462.6 days, and 115Cd with a half-life of 53.46 hours. All of the remaining radioactive isotopes have half-lives of less than 2.5 hours, and the majority have half-lives of less than 5 minutes. Cadmium has 8 known [meta states](https://en.wikipedia.org/wiki/Meta_state), with the most stable being 113mCd (*t*1⁄2 = 14.1 years), 115mCd (*t*1⁄2 = 44.6 days), and 117mCd (*t*1⁄2 = 3.36 hours).[[9]](https://en.wikipedia.org/wiki/Cadmium#cite_note-NUBASE-9)

The known isotopes of cadmium range in [atomic mass](https://en.wikipedia.org/wiki/Atomic_mass) from 94.950 [u](https://en.wikipedia.org/wiki/Atomic_mass_unit) (95Cd) to 131.946 u (132Cd). For isotopes lighter than 112 u, the primary [decay mode](https://en.wikipedia.org/wiki/Decay_mode) is [electron capture](https://en.wikipedia.org/wiki/Electron_capture) and the dominant [decay product](https://en.wikipedia.org/wiki/Decay_product) is element 47 ([silver](https://en.wikipedia.org/wiki/Silver)). Heavier isotopes decay mostly through [beta emission](https://en.wikipedia.org/wiki/Beta_emission) producing element 49 ([indium](https://en.wikipedia.org/wiki/Indium)).[[9]](https://en.wikipedia.org/wiki/Cadmium#cite_note-NUBASE-9)

One isotope of cadmium, 113Cd, absorbs neutrons with high selectivity: With very high probability, neutrons with energy below the *cadmium cut-off* will be absorbed; those higher than the *cut-off will be transmitted*. The cadmium cut-off is about 0.5 eV, and neutrons below that level are deemed slow neutrons, distinct from intermediate and fast neutrons.[[10]](https://en.wikipedia.org/wiki/Cadmium#cite_note-10)

Cadmium is created via the [s-process](https://en.wikipedia.org/wiki/S-process) in low- to medium-mass stars with masses of 0.6 to 10 [solar masses](https://en.wikipedia.org/wiki/Sun), over thousands of years. In that process, a [silver](https://en.wikipedia.org/wiki/Silver) atom captures a [neutron](https://en.wikipedia.org/wiki/Neutron) and then undergoes [beta decay](https://en.wikipedia.org/wiki/Beta_decay).[[11]](https://en.wikipedia.org/wiki/Cadmium#cite_note-11)

**History**

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

[Friedrich Stromeyer](https://en.wikipedia.org/wiki/Friedrich_Stromeyer)

Cadmium ([Latin](https://en.wikipedia.org/wiki/Latin) *cadmia*, [Greek](https://en.wikipedia.org/wiki/Greek_language) *καδμεία* meaning "[calamine](https://en.wikipedia.org/wiki/Calamine_(mineral))", a cadmium-bearing mixture of minerals that was named after the Greek mythological character Κάδμος, [Cadmus](https://en.wikipedia.org/wiki/Cadmus), the founder of [Thebes](https://en.wikipedia.org/wiki/Ancient_Thebes_(Boeotia))) was [discovered](https://en.wikipedia.org/wiki/Discovery_of_the_chemical_elements) simultaneously in 1817 by [Friedrich Stromeyer](https://en.wikipedia.org/wiki/Friedrich_Stromeyer)[[12]](https://en.wikipedia.org/wiki/Cadmium#cite_note-12) and [Karl Samuel Leberecht Hermann](https://en.wikipedia.org/wiki/Karl_Samuel_Leberecht_Hermann), both in [Germany](https://en.wikipedia.org/wiki/Germany), as an impurity in zinc carbonate.[[4]](https://en.wikipedia.org/wiki/Cadmium#cite_note-ReferenceA-4) Stromeyer found the new element as an impurity in [zinc carbonate](https://en.wikipedia.org/wiki/Zinc_carbonate) (calamine), and, for 100 years, Germany remained the only important producer of the metal. The metal was named after the Latin word for calamine, because it was found in this zinc ore. Stromeyer noted that some impure samples of calamine changed color when heated but pure calamine did not. He was persistent in studying these results and eventually isolated cadmium metal by [roasting](https://en.wikipedia.org/wiki/Roasting_(metallurgy)) and reducing the [sulfide](https://en.wikipedia.org/wiki/Cadmium_sulfide). The potential for cadmium yellow as pigment was recognized in the 1840s, but the lack of cadmium limited this application.[[13]](https://en.wikipedia.org/wiki/Cadmium#cite_note-13)[[14]](https://en.wikipedia.org/wiki/Cadmium#cite_note-14)[[15]](https://en.wikipedia.org/wiki/Cadmium#cite_note-Cadold-15)

Even though cadmium and its compounds are toxic in certain forms and concentrations, the [British Pharmaceutical Codex](https://en.wikipedia.org/wiki/British_Pharmaceutical_Codex) from 1907 states that [cadmium iodide](https://en.wikipedia.org/wiki/Cadmium_iodide) was used as a [medication](https://en.wikipedia.org/wiki/Medication) to treat "enlarged joints, scrofulous glands, and chilblains".[[16]](https://en.wikipedia.org/wiki/Cadmium#cite_note-16)

In 1907, the [International Astronomical Union](https://en.wikipedia.org/wiki/International_Astronomical_Union) defined the international [ångström](https://en.wikipedia.org/wiki/%C3%85ngstr%C3%B6m) in terms of a red cadmium spectral line (1 wavelength = 6438.46963 Å).[[17]](https://en.wikipedia.org/wiki/Cadmium#cite_note-17)[[18]](https://en.wikipedia.org/wiki/Cadmium#cite_note-18) This was adopted by the 7th [General Conference on Weights and Measures](https://en.wikipedia.org/wiki/General_Conference_on_Weights_and_Measures) in 1927. In 1960, the definitions of both the [metre](https://en.wikipedia.org/wiki/Metre) and ångström were changed to use [krypton](https://en.wikipedia.org/wiki/Krypton).[[19]](https://en.wikipedia.org/wiki/Cadmium#cite_note-19)

After the industrial scale production of cadmium started in the 1930s and 1940s, the major application of cadmium was the coating of iron and steel to prevent corrosion; in 1944, 62% and in 1956, 59% of the cadmium in the United States was used for [plating](https://en.wikipedia.org/wiki/Plating).[[4]](https://en.wikipedia.org/wiki/Cadmium#cite_note-ReferenceA-4)[[20]](https://en.wikipedia.org/wiki/Cadmium#cite_note-YB1956-20) In 1956, 24% of the cadmium in the United States was used for a second application in red, orange and yellow pigments from sulfides and selenides of cadmium.[[20]](https://en.wikipedia.org/wiki/Cadmium#cite_note-YB1956-20)

The stabilizing effect of cadmium chemicals like the carboxylates cadmium laurate and cadmium stearate on [PVC](https://en.wikipedia.org/wiki/Pvc) led to an increased use of those compounds in the 1970s and 1980s. The demand for cadmium in pigments, coatings, stabilizers, and alloys declined as a result of environmental and health regulations in the 1980s and 1990s; in 2006, only 7% of to total cadmium consumption was used for plating, and only 10% was used for pigments.[[4]](https://en.wikipedia.org/wiki/Cadmium#cite_note-ReferenceA-4) At the same time, these decreases in consumption were compensated by a growing demand for cadmium for nickel-cadmium batteries, which accounted for 81% of the cadmium consumption in the United States in 2006.[[21]](https://en.wikipedia.org/wiki/Cadmium#cite_note-usgs-21)

**Occurrence**

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

Cadmium metal

See also: [Category:Cadmium minerals](https://en.wikipedia.org/wiki/Category:Cadmium_minerals)

Cadmium makes up about 0.1 [ppm](https://en.wikipedia.org/wiki/Parts_per_million) of [Earth's crust](https://en.wikipedia.org/wiki/Earth%27s_crust). It is much rarer than zinc, which makes up about 65 ppm.[[22]](https://en.wikipedia.org/wiki/Cadmium#cite_note-22) No significant deposits of cadmium-containing ores are known. The only cadmium [mineral](https://en.wikipedia.org/wiki/Mineral) of importance, [greenockite](https://en.wikipedia.org/wiki/Greenockite) (Cd[S](https://en.wikipedia.org/wiki/Sulfur)), is nearly always associated with [sphalerite](https://en.wikipedia.org/wiki/Sphalerite) (ZnS). This association is caused by geochemical similarity between zinc and cadmium, with no geological process likely to separate them. Thus, cadmium is produced mainly as a byproduct of mining, smelting, and refining sulfidic ores of zinc, and, to a lesser degree, [lead](https://en.wikipedia.org/wiki/Lead) and [copper](https://en.wikipedia.org/wiki/Copper). Small amounts of cadmium, about 10% of consumption, are produced from secondary sources, mainly from dust generated by recycling iron and steel scrap. Production in the United States began in 1907,[[15]](https://en.wikipedia.org/wiki/Cadmium#cite_note-Cadold-15) but wide use began after World War I.[[23]](https://en.wikipedia.org/wiki/Cadmium#cite_note-price-23)[[24]](https://en.wikipedia.org/wiki/Cadmium#cite_note-lifecycle-24)

Metallic cadmium can be found in the [Vilyuy River](https://en.wikipedia.org/wiki/Vilyuy_River) basin in [Siberia](https://en.wikipedia.org/wiki/Siberia).[[25]](https://en.wikipedia.org/wiki/Cadmium#cite_note-25)

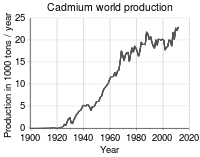
Rocks mined for phosphate fertilizers contain varying amounts of cadmium, resulting in a cadmium concentration of as much as 300 mg/kg in the fertilizers and a high cadmium content in agricultural soils.[[26]](https://en.wikipedia.org/wiki/Cadmium#cite_note-26)[[27]](https://en.wikipedia.org/wiki/Cadmium#cite_note-27) Coal can contain significant amounts of cadmium, which ends up mostly in flue dust.[[28]](https://en.wikipedia.org/wiki/Cadmium#cite_note-28) Cadmium in soil can be absorbed by crops such as rice. [Chinese](https://en.wikipedia.org/wiki/China) [ministry of agriculture](https://en.wikipedia.org/wiki/Ministry_of_Agriculture_of_the_People%27s_Republic_of_China) measured in 2002 that 28% of [rice](https://en.wikipedia.org/wiki/Rice) it sampled had excess lead and 10% had excess cadmium above limits defined by law. Some plants such as [willow trees](https://en.wikipedia.org/wiki/Willow) and [poplars](https://en.wikipedia.org/wiki/Populus) have been found to clean both lead and cadmium from soil.[[29]](https://en.wikipedia.org/wiki/Cadmium#cite_note-29)

Typical background concentrations of cadmium do not exceed 5 ng/m3 in the atmosphere; 2 mg/kg in soil; 1 μg/L in freshwater and 50 ng/L in seawater.[[30]](https://en.wikipedia.org/wiki/Cadmium#cite_note-30)

**Production**

The [British Geological Survey](https://en.wikipedia.org/wiki/British_Geological_Survey) reports that in 2001, China was the top producer of cadmium with almost one-sixth of the world's production, closely followed by South Korea and Japan.[[31]](https://en.wikipedia.org/wiki/Cadmium#cite_note-31)

Cadmium is a common impurity in [zinc](https://en.wikipedia.org/wiki/Zinc) ores, and it is most often isolated during the production of zinc. Some zinc ores concentrates from sulfidic zinc ores contain up to 1.4% of cadmium.[[32]](https://en.wikipedia.org/wiki/Cadmium#cite_note-Cd-Trend-32) In the 1970s, the output of cadmium was 6.5 pounds per ton of zinc.[[32]](https://en.wikipedia.org/wiki/Cadmium#cite_note-Cd-Trend-32) Zinc [sulfide](https://en.wikipedia.org/wiki/Sulfide) ores are roasted in the presence of [oxygen](https://en.wikipedia.org/wiki/Oxygen), converting the zinc sulfide to the [oxide](https://en.wikipedia.org/wiki/Oxide). Zinc metal is produced either by [smelting](https://en.wikipedia.org/wiki/Smelting) the oxide with [carbon](https://en.wikipedia.org/wiki/Carbon) or by [electrolysis](https://en.wikipedia.org/wiki/Electrolysis) in [sulfuric acid](https://en.wikipedia.org/wiki/Sulfuric_acid). Cadmium is isolated from the zinc metal by [vacuum distillation](https://en.wikipedia.org/wiki/Vacuum_distillation) if the zinc is smelted, or cadmium sulfate is [precipitated](https://en.wikipedia.org/wiki/Precipitate) from the electrolysis solution.[[24]](https://en.wikipedia.org/wiki/Cadmium#cite_note-lifecycle-24)[[33]](https://en.wikipedia.org/wiki/Cadmium#cite_note-33)

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

History of the world production of cadmium

* [](https://en.wikipedia.org/wiki/File:2005cadmium.PNG)

Cadmium output in 2005

**Applications**

Cadmium is a common component of electric batteries, [pigments](https://en.wikipedia.org/wiki/Cadmium_pigments),[[34]](https://en.wikipedia.org/wiki/Cadmium#cite_note-colors-34) coatings,[[35]](https://en.wikipedia.org/wiki/Cadmium#cite_note-fff-35) and electroplating.[[36]](https://en.wikipedia.org/wiki/Cadmium#cite_note-HgCdPb-36)

**Batteries**

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

Ni-Cd batteries

In 2009, 86% of cadmium was used in [batteries](https://en.wikipedia.org/wiki/Battery_(electricity)), predominantly in [rechargeable](https://en.wikipedia.org/wiki/Rechargeable_battery) [nickel-cadmium batteries](https://en.wikipedia.org/wiki/Nickel-cadmium_battery). Nickel-cadmium cells have a nominal cell potential of 1.2 [V](https://en.wikipedia.org/wiki/Volt). The cell consists of a positive [nickel hydroxide](https://en.wikipedia.org/wiki/Nickel_hydroxide) [electrode](https://en.wikipedia.org/wiki/Electrode) and a negative cadmium electrode plate separated by an [alkaline](https://en.wikipedia.org/wiki/Alkaline) [electrolyte](https://en.wikipedia.org/wiki/Electrolyte) ([potassium hydroxide](https://en.wikipedia.org/wiki/Potassium_hydroxide)).[[37]](https://en.wikipedia.org/wiki/Cadmium#cite_note-37) The European Union put a limit on cadmium in electronics in 2004 of 0.01%,[[38]](https://en.wikipedia.org/wiki/Cadmium#cite_note-38) with some exceptions, and reduced the limit on cadmium content to 0.002%.[[39]](https://en.wikipedia.org/wiki/Cadmium#cite_note-39) Another type of battery based on cadmium is the [silver-cadmium battery](https://en.wikipedia.org/wiki/Silver-cadmium_battery).

**Electroplating**

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

A photograph and representative spectrum of [photoluminescence](https://en.wikipedia.org/wiki/Photoluminescence) from colloidal CdSe [quantum dots](https://en.wikipedia.org/wiki/Quantum_dot)

Cadmium [electroplating](https://en.wikipedia.org/wiki/Electroplating), consuming 6% of the global production, is used in the aircraft industry to reduce [corrosion](https://en.wikipedia.org/wiki/Corrosion) of steel components.[[36]](https://en.wikipedia.org/wiki/Cadmium#cite_note-HgCdPb-36) This coating is passivated by [chromate](https://en.wikipedia.org/wiki/Chromate) salts.[[35]](https://en.wikipedia.org/wiki/Cadmium#cite_note-fff-35) A limitation of cadmium plating is [hydrogen embrittlement](https://en.wikipedia.org/wiki/Hydrogen_embrittlement) of high-strength steels from the electroplating process. Therefore, steel parts heat-treated to tensile strength above 1300 MPa (200 ksi) should be coated by an alternative method (such as special low-embrittlement cadmium electroplating processes or physical vapor deposition).

Titanium embrittlement from cadmium-plated tool residues resulted in banishment of those tools (and the implementation of routine tool testing to detect cadmium contamination) in the A-12/SR-71, U-2, and subsequent aircraft programs that use titanium.[[40]](https://en.wikipedia.org/wiki/Cadmium#cite_note-40)

**Nuclear fission**

Cadmium is used in the control rods of nuclear reactors, acting as a very effective "neutron poison" to control [neutron flux](https://en.wikipedia.org/wiki/Neutron_flux) in [nuclear fission](https://en.wikipedia.org/wiki/Nuclear_fission).[[36]](https://en.wikipedia.org/wiki/Cadmium#cite_note-HgCdPb-36) When cadmium rods are inserted in the core of a nuclear reactor, cadmium absorbs neutrons, preventing them from creating additional fission events, thus controlling the amount of reactivity. The [pressurized water reactor](https://en.wikipedia.org/wiki/Pressurized_water_reactor) designed by [Westinghouse Electric Company](https://en.wikipedia.org/wiki/Westinghouse_Electric_Company) uses an alloy consisting of 80% silver, 15% indium, and 5% cadmium.[[36]](https://en.wikipedia.org/wiki/Cadmium#cite_note-HgCdPb-36)

**Televisions**

[QLED TVs](https://en.wikipedia.org/wiki/Quantum_dot_display) have been starting to include cadmium in construction. Some companies have been looking to reduce the environmental impact of human exposure and pollution of the material in televisions during production.[[41]](https://en.wikipedia.org/wiki/Cadmium#cite_note-41)

**Compounds**

[](https://en.wikipedia.org/wiki/File:Tyne_and_Wear_Metro_train_4001_at_Pelaw_01.jpg)

Train painted with [cadmium orange](https://en.wikipedia.org/wiki/Cadmium_pigments)

[Cadmium oxide](https://en.wikipedia.org/wiki/Cadmium_oxide) was used in black and white television phosphors and in the blue and green phosphors of color television cathode ray tubes.[[42]](https://en.wikipedia.org/wiki/Cadmium#cite_note-42) [Cadmium sulfide](https://en.wikipedia.org/wiki/Cadmium_sulfide) (CdS) is used as a photoconductive surface coating for photocopier drums.[[43]](https://en.wikipedia.org/wiki/Cadmium#cite_note-43)

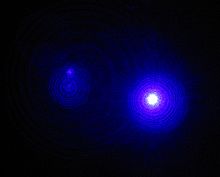
[](https://en.wikipedia.org/wiki/File:Cadmium_sulfide.jpg)

Cadmium sulfide

Various cadmium salts are used in paint pigments, with CdS as a [yellow pigment](https://en.wikipedia.org/wiki/Cadmium_pigments) being the most common. [Cadmium selenide](https://en.wikipedia.org/wiki/Cadmium_selenide) is a red pigment, commonly called *cadmium red*. To painters who work with the pigment, cadmium provides the most brilliant and durable yellows, oranges, and reds — so much so that during production, these colors are significantly toned down before they are ground with oils and binders or blended into [watercolors](https://en.wikipedia.org/wiki/Watercolor), [gouaches](https://en.wikipedia.org/wiki/Gouache), [acrylics](https://en.wikipedia.org/wiki/Acrylic_paint), and other paint and pigment formulations. Because these pigments are potentially toxic, users should use a [barrier cream](https://en.wikipedia.org/wiki/Barrier_cream) on the hands to prevent absorption through the skin[[34]](https://en.wikipedia.org/wiki/Cadmium#cite_note-colors-34) even though the amount of cadmium absorbed into the body through the skin is reported to be less than 1%.[[6]](https://en.wikipedia.org/wiki/Cadmium#cite_note-ATSDR-6)

In [PVC](https://en.wikipedia.org/wiki/Polyvinyl_chloride), cadmium was used as heat, light, and weathering stabilizers.[[36]](https://en.wikipedia.org/wiki/Cadmium#cite_note-HgCdPb-36)[[44]](https://en.wikipedia.org/wiki/Cadmium#cite_note-44) Currently, cadmium stabilizers have been completely replaced with barium-zinc, calcium-zinc and organo-tin stabilizers. Cadmium is used in many kinds of [solder](https://en.wikipedia.org/wiki/Solder) and bearing alloys, because it has a low [coefficient of friction](https://en.wikipedia.org/wiki/Coefficient_of_friction) and fatigue resistance.[[36]](https://en.wikipedia.org/wiki/Cadmium#cite_note-HgCdPb-36) It is also found in some of the lowest-melting [alloys](https://en.wikipedia.org/wiki/Alloy), such as [Wood's metal](https://en.wikipedia.org/wiki/Wood%27s_metal).[[45]](https://en.wikipedia.org/wiki/Cadmium#cite_note-45)

**Laboratory uses**

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

Violet light from a [helium](https://en.wikipedia.org/wiki/Helium) cadmium metal vapor [laser](https://en.wikipedia.org/wiki/Laser). The highly [monochromatic](https://en.wikipedia.org/wiki/Monochromatic) color arises from the 441.563 nm transition [line](https://en.wikipedia.org/wiki/Spectral_line) of cadmium.

Helium–cadmium lasers are a common source of blue-ultraviolet laser light. They operate at either 325 or 422 nm in [fluorescence microscopes](https://en.wikipedia.org/wiki/Fluorescence_microscope) and various laboratory experiments.[[46]](https://en.wikipedia.org/wiki/Cadmium#cite_note-46)[[47]](https://en.wikipedia.org/wiki/Cadmium#cite_note-47) Cadmium selenide [quantum dots](https://en.wikipedia.org/wiki/Quantum_dot) emit bright [luminescence](https://en.wikipedia.org/wiki/Luminescence) under UV excitation (He-Cd laser, for example). The color of this luminescence can be green, yellow or red depending on the particle size. Colloidal solutions of those particles are used for imaging of biological tissues and solutions with a [fluorescence microscope](https://en.wikipedia.org/wiki/Fluorescence_microscope).[[48]](https://en.wikipedia.org/wiki/Cadmium#cite_note-48)

Cadmium is a component of some compound [semiconductors](https://en.wikipedia.org/wiki/Semiconductor), such as cadmium sulfide, cadmium selenide, and [cadmium telluride](https://en.wikipedia.org/wiki/Cadmium_telluride), used for light detection and [solar cells](https://en.wikipedia.org/wiki/Solar_cell). [HgCdTe](https://en.wikipedia.org/wiki/HgCdTe) is sensitive to [infrared](https://en.wikipedia.org/wiki/Infrared)[[36]](https://en.wikipedia.org/wiki/Cadmium#cite_note-HgCdPb-36) light and can be used as an infrared detector, motion detector, or switch in remote control devices.

In molecular biology, cadmium is used to block voltage-dependent calcium channels from fluxing calcium ions, as well as in [hypoxia](https://en.wikipedia.org/wiki/Hypoxia_(medical)) research to stimulate [proteasome](https://en.wikipedia.org/wiki/Proteasome)-dependent degradation of [Hif-1α](https://en.wikipedia.org/wiki/Hypoxia-inducible_factors).[[49]](https://en.wikipedia.org/wiki/Cadmium#cite_note-49)

**Cadmium-selective sensors**

Cadmium-selective sensors based on the [fluorophore](https://en.wikipedia.org/wiki/Fluorophore) [BODIPY](https://en.wikipedia.org/wiki/BODIPY) have been developed for imaging and sensing of cadmium in cells.[[50]](https://en.wikipedia.org/wiki/Cadmium#cite_note-50) One of the most popular way to monitor cadmium in aqueous environments is the use of [electrochemistry](https://en.wikipedia.org/wiki/Electrochemistry), one example is by attaching a [self-assembled monolayer](https://en.wikipedia.org/wiki/Self-assembled_monolayer) that can help obtain a cadmium selective electrode with a [ppt](https://en.wikipedia.org/wiki/Parts-per_notation)-level sensitivity.[[51]](https://en.wikipedia.org/wiki/Cadmium#cite_note-51)

**Biological role and research**

Cadmium has no known function in higher organisms,[[52]](https://en.wikipedia.org/wiki/Cadmium#cite_note-52) but a cadmium-dependent [carbonic anhydrase](https://en.wikipedia.org/wiki/Carbonic_anhydrase) has been found in some marine [diatoms](https://en.wikipedia.org/wiki/Diatom).[[53]](https://en.wikipedia.org/wiki/Cadmium#cite_note-Diatom-53) The diatoms live in environments with very low zinc concentrations and cadmium performs the function normally carried out by zinc in other anhydrases. This was discovered with X-ray absorption fluorescence spectroscopy (XAFS).[[53]](https://en.wikipedia.org/wiki/Cadmium#cite_note-Diatom-53)[[54]](https://en.wikipedia.org/wiki/Cadmium#cite_note-54)

The highest concentration of cadmium is absorbed in the kidneys of humans, and up to about 30 mg of cadmium is commonly inhaled throughout human childhood and adolescence.[[55]](https://en.wikipedia.org/wiki/Cadmium#cite_note-55) Cadmium is under preliminary research for its [toxicity](https://en.wikipedia.org/wiki/Toxicity) in humans, potentially affecting mechanisms and risks of [cancer](https://en.wikipedia.org/wiki/Cancer), [cardiovascular disease](https://en.wikipedia.org/wiki/Cardiovascular_disease), and [osteoporosis](https://en.wikipedia.org/wiki/Osteoporosis).[[56]](https://en.wikipedia.org/wiki/Cadmium#cite_note-56)[[57]](https://en.wikipedia.org/wiki/Cadmium#cite_note-57)[[58]](https://en.wikipedia.org/wiki/Cadmium#cite_note-58)[[59]](https://en.wikipedia.org/wiki/Cadmium#cite_note-59)

Cadmium is a common contaminant of fluoridation chemicals used as water additives. [[60]](https://en.wikipedia.org/wiki/Cadmium#cite_note-60)Fluoride additives are sourced from both the phosphate fertilizer industry and metal industry.

**Environment**

The biogeochemistry of cadmium and its release to the environment has been the subject of review, as has the speciation of cadmium in the environment.[[61]](https://en.wikipedia.org/wiki/Cadmium#cite_note-61)[[62]](https://en.wikipedia.org/wiki/Cadmium#cite_note-62)

**Safety**

Main article: [Cadmium poisoning](https://en.wikipedia.org/wiki/Cadmium_poisoning)

|  |  |
| --- | --- |
| Cadmium | |
| **Hazards** | |
| [GHS pictograms](https://en.wikipedia.org/wiki/GHS_hazard_pictograms) | [The skull-and-crossbones pictogram in the Globally Harmonized System of Classification and Labelling of Chemicals (GHS)](https://en.wikipedia.org/wiki/File:GHS-pictogram-skull.svg)[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)[The environment pictogram in the Globally Harmonized System of Classification and Labelling of Chemicals (GHS)](https://en.wikipedia.org/wiki/File:GHS-pictogram-pollu.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) | H330, H341 |
| [GHS precautionary statements](https://en.wikipedia.org/wiki/GHS_precautionary_statements) | P201, P202, P260, P264, P270, P271, P273, P280, P284, P304, P340, P310, P308, P313, P403, P233, P405, P501[[63]](https://en.wikipedia.org/wiki/Cadmium#cite_note-63) |
| [NFPA 704](https://en.wikipedia.org/wiki/NFPA_704) | NFPA 704 four-colored diamond  [0](https://en.wikipedia.org/wiki/NFPA_704#Red)  [4](https://en.wikipedia.org/wiki/NFPA_704#Blue)  [0](https://en.wikipedia.org/wiki/NFPA_704#Yellow) |

Individuals and organizations have been reviewing cadmium's bioinorganic aspects for its toxicity.[[64]](https://en.wikipedia.org/wiki/Cadmium#cite_note-64) The most dangerous form of occupational exposure to cadmium is inhalation of fine dust and fumes, or ingestion of highly soluble cadmium compounds.[[4]](https://en.wikipedia.org/wiki/Cadmium#cite_note-ReferenceA-4) Inhalation of cadmium fumes can result initially in [metal fume fever](https://en.wikipedia.org/wiki/Metal_fume_fever) but may progress to chemical [pneumonitis](https://en.wikipedia.org/wiki/Pneumonitis), [pulmonary edema](https://en.wikipedia.org/wiki/Pulmonary_edema), and death.[[65]](https://en.wikipedia.org/wiki/Cadmium#cite_note-65)

Cadmium is also an environmental hazard. Human exposure is primarily from fossil fuel combustion, phosphate fertilizers, natural sources, iron and steel production, cement production and related activities, nonferrous metals production, and municipal solid waste incineration.[[4]](https://en.wikipedia.org/wiki/Cadmium#cite_note-ReferenceA-4) Bread, root crops, and vegetables also contribute to the cadmium in modern populations.[[66]](https://en.wikipedia.org/wiki/Cadmium#cite_note-news.yahoo.com-66)

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

[Jinzū River](https://en.wikipedia.org/wiki/Jinz%C5%AB_River) area, which was contaminated with cadmium

There have been a few instances of general population poisoning as the result of long-term exposure to cadmium in contaminated food and water, and research into an estrogen mimicry that may induce breast cancer is ongoing.[[66]](https://en.wikipedia.org/wiki/Cadmium#cite_note-news.yahoo.com-66) In the decades leading up to [World War II](https://en.wikipedia.org/wiki/World_War_II), mining operations contaminated the [Jinzū River](https://en.wikipedia.org/wiki/Jinz%C5%AB_River) in Japan with cadmium and traces of other toxic metals. As a consequence, cadmium accumulated in the rice crops along the riverbanks downstream of the mines. Some members of the local agricultural communities consumed the contaminated rice and developed [itai-itai](https://en.wikipedia.org/wiki/Itai-itai) disease and renal abnormalities, including [proteinuria](https://en.wikipedia.org/wiki/Proteinuria) and [glucosuria](https://en.wikipedia.org/wiki/Glucosuria).[[67]](https://en.wikipedia.org/wiki/Cadmium#cite_note-67) The victims of this poisoning were almost exclusively post-menopausal women with low iron and other mineral body stores. Similar general population cadmium exposures in other parts of the world have not resulted in the same health problems because the populations maintained sufficient iron and other mineral levels. Thus, although cadmium is a major factor in the itai-itai disease in Japan, most researchers have concluded that it was one of several factors.[[4]](https://en.wikipedia.org/wiki/Cadmium#cite_note-ReferenceA-4)

Cadmium is one of six substances banned by the European Union's [Restriction on Hazardous Substances](https://en.wikipedia.org/wiki/ROHS) (RoHS) directive, which regulates hazardous substances in electrical and electronic equipment but allows for certain exemptions and exclusions from the scope of the law.[[68]](https://en.wikipedia.org/wiki/Cadmium#cite_note-68) The International Agency for Research on Cancer has classified cadmium and cadmium compounds as carcinogenic to humans.[[69]](https://en.wikipedia.org/wiki/Cadmium#cite_note-69) Although occupational exposure to cadmium is linked to lung and prostate cancer, there is still a substantial controversy about the carcinogenicity of cadmium in low environmental exposure. Recent data from epidemiological studies suggest that intake of cadmium through diet associates to higher risk of endometrial, breast and prostate cancer as well as to osteoporosis in humans.[[70]](https://en.wikipedia.org/wiki/Cadmium#cite_note-70)[[71]](https://en.wikipedia.org/wiki/Cadmium#cite_note-71)[[72]](https://en.wikipedia.org/wiki/Cadmium#cite_note-72)[[73]](https://en.wikipedia.org/wiki/Cadmium#cite_note-73) A recent study has demonstrated that endometrial tissue is characterized by higher levels of cadmium in current and former smoking females.[[74]](https://en.wikipedia.org/wiki/Cadmium#cite_note-74)

Cadmium exposure is a risk factor associated with a large number of illnesses including kidney disease,[[75]](https://en.wikipedia.org/wiki/Cadmium#cite_note-zn-cd.diseases-75) early atherosclerosis, hypertension, and cardiovascular diseases.[[76]](https://en.wikipedia.org/wiki/Cadmium#cite_note-76) Although studies show a significant correlation between cadmium exposure and occurrence of disease in human populations, a necessary molecular mechanism has not been identified. One hypothesis holds that cadmium is an [endocrine disruptor](https://en.wikipedia.org/wiki/Endocrine_disruptor) and some experimental studies have shown that it can interact with different [hormonal](https://en.wikipedia.org/wiki/Hormone) signaling pathways. For example, cadmium can bind to the [estrogen receptor](https://en.wikipedia.org/wiki/Estrogen_receptor) alpha,[[77]](https://en.wikipedia.org/wiki/Cadmium#cite_note-77)[[78]](https://en.wikipedia.org/wiki/Cadmium#cite_note-78) and affect signal transduction along the [estrogen](https://en.wikipedia.org/wiki/Estrogen) and [MAPK](https://en.wikipedia.org/wiki/MAPK) signaling pathways at low doses.[[79]](https://en.wikipedia.org/wiki/Cadmium#cite_note-79)[[80]](https://en.wikipedia.org/wiki/Cadmium#cite_note-80)[[81]](https://en.wikipedia.org/wiki/Cadmium#cite_note-81)

The [tobacco plant](https://en.wikipedia.org/wiki/Tobacco_plant) readily absorbs and accumulates [heavy metals](https://en.wikipedia.org/wiki/Heavy_metals), such as cadmium from the surrounding soil into its leaves. These are readily absorbed into the user's body following smoke inhalation.[[82]](https://en.wikipedia.org/wiki/Cadmium#cite_note-82) Tobacco smoking is the most important single source of cadmium exposure in the general population. An estimated 10% of the cadmium content of a cigarette is inhaled through smoking. Absorption of cadmium through the lungs is more effective than through the gut, and as much as 50% of the cadmium inhaled in cigarette smoke may be absorbed.[[83]](https://en.wikipedia.org/wiki/Cadmium#cite_note-83) On average, cadmium concentrations in the blood of smokers is 4 times 5 times greater and in the kidney, 2–3 times greater than non-smokers. Despite the high cadmium content in cigarette smoke, there seems to be little exposure to cadmium from [passive smoking](https://en.wikipedia.org/wiki/Passive_smoking).[[84]](https://en.wikipedia.org/wiki/Cadmium#cite_note-84)

In a non-smoking population, food is the greatest source of exposure. High quantities of cadmium can be found in [crustaceans](https://en.wikipedia.org/wiki/Crustacean), [mollusks](https://en.wikipedia.org/wiki/Mollusca), [offal](https://en.wikipedia.org/wiki/Offal), and [algae](https://en.wikipedia.org/wiki/Algae) products. However, grains, vegetables, and starchy roots and tubers are consumed in much greater quantity in the US, and are the source of the greatest dietary exposure.[[85]](https://en.wikipedia.org/wiki/Cadmium#cite_note-efsa.europa.eu-85) Most plants bio-accumulate metal toxins like Cd, and when composted to form organic fertilizers yield a product which can often contain high amounts (e.g., over 0.5 mg) of metal toxins for every kilo of fertilizer. Fertilizers made from animal dung (e.g., cow dung) or urban waste can contain similar amounts of Cd. The Cd added to the soil from fertilizers (rock phosphates or organic fertilizers) become bio-available and toxic only if the soil pH is low (i.e., acidic soils). Zinc is chemically similar to cadmium and some evidence indicates the presence of Zn ions reduces cadmium toxicity.[[86]](https://en.wikipedia.org/wiki/Cadmium#cite_note-86)

Zinc, Cu, Ca, and Fe ions, and selenium with vitamin C are used to treat Cd intoxication, though it is not easily reversed.[[75]](https://en.wikipedia.org/wiki/Cadmium#cite_note-zn-cd.diseases-75)

**Regulations**

Because of the adverse effects of cadmium on the environment and human health, the supply and use of cadmium is restricted in Europe under the [REACH Regulation](https://en.wikipedia.org/wiki/REACH_Regulation).[[87]](https://en.wikipedia.org/wiki/Cadmium#cite_note-87)

The EFSA Panel on Contaminants in the Food Chain specifies that 2.5 μg/kg body weight is a tolerable weekly intake for humans.[[85]](https://en.wikipedia.org/wiki/Cadmium#cite_note-efsa.europa.eu-85) The Joint FAO/WHO Expert Committee on Food Additives has declared 7 μg/kg bw to be the provisional tolerable weekly intake level.[[88]](https://en.wikipedia.org/wiki/Cadmium#cite_note-88)

The US [Occupational Safety and Health Administration](https://en.wikipedia.org/wiki/Occupational_Safety_and_Health_Administration) (OSHA) has set the [permissible exposure limit](https://en.wikipedia.org/wiki/Permissible_exposure_limit) (PEL) for cadmium at a time-weighted average (TWA) of 0.005 ppm. The [National Institute for Occupational Safety and Health](https://en.wikipedia.org/wiki/National_Institute_for_Occupational_Safety_and_Health) (NIOSH) has not set a [recommended exposure limit](https://en.wikipedia.org/wiki/Recommended_exposure_limit) (REL) and has designated cadmium as a known human carcinogen. The [IDLH](https://en.wikipedia.org/wiki/IDLH) (immediately dangerous to life and health) level for cadmium is 9 mg/m3.[[89]](https://en.wikipedia.org/wiki/Cadmium#cite_note-89)

|  |  |  |  |
| --- | --- | --- | --- |
| **Lethal dose**[**[90]**](https://en.wikipedia.org/wiki/Cadmium#cite_note-90) | **Organism** | **Route** | **Time** |
| LD50: 225 mg/kg | rat | oral | n/a |
| LD50: 890 mg/kg | mouse | oral | n/a |
| LC50: 25 mg/m3 | rat | n/a | 30 min |

**Product recalls**

In May 2006, a sale of the seats from [Arsenal F.C.](https://en.wikipedia.org/wiki/Arsenal_F.C.)'s old stadium, [Highbury](https://en.wikipedia.org/wiki/Arsenal_Stadium) in London, England was cancelled when the seats were discovered to contain trace amounts of cadmium.[[91]](https://en.wikipedia.org/wiki/Cadmium#cite_note-91) Reports of high levels of cadmium use in children's jewelry in 2010 led to a US [Consumer Product Safety Commission](https://en.wikipedia.org/wiki/Consumer_Product_Safety_Commission) investigation.[[92]](https://en.wikipedia.org/wiki/Cadmium#cite_note-92) The U.S. CPSC issued specific recall notices for cadmium content in jewelry sold by [Claire's](https://en.wikipedia.org/wiki/Claire%27s)[[93]](https://en.wikipedia.org/wiki/Cadmium#cite_note-93) and [Wal-Mart](https://en.wikipedia.org/wiki/Wal-Mart)[[94]](https://en.wikipedia.org/wiki/Cadmium#cite_note-94) stores.

In June 2010, [McDonald's](https://en.wikipedia.org/wiki/McDonald%27s) voluntarily recalled more than 12 million promotional "Shrek Forever After 3D" Collectable Drinking Glasses because of the cadmium levels in paint pigments on the glassware.[[95]](https://en.wikipedia.org/wiki/Cadmium#cite_note-95) The glasses were manufactured by [Arc International](https://en.wikipedia.org/wiki/Arc_International_(tableware)), of [Millville, NJ](https://en.wikipedia.org/wiki/Millville,_NJ), USA.[[96]](https://en.wikipedia.org/wiki/Cadmium#cite_note-96)

**See also**

* [Cadmium pigments](https://en.wikipedia.org/wiki/Cadmium_pigments)
* [Cadmium telluride](https://en.wikipedia.org/wiki/Cadmium_telluride)
* [Red List building materials](https://en.wikipedia.org/wiki/Red_List_building_materials)
* [Toxic heavy metal](https://en.wikipedia.org/wiki/Toxic_heavy_metal)

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  *Weast, Robert (1984). CRC, Handbook of Chemistry and Physics. Boca Raton, Florida: Chemical Rubber Company Publishing. pp. E110.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*0-8493-0464-4*](https://en.wikipedia.org/wiki/Special:BookSources/0-8493-0464-4)*.*

  *Morrow, H. (2010). "Cadmium and Cadmium Alloys".* [*Kirk-Othmer Encyclopedia of Chemical Technology*](https://en.wikipedia.org/w/index.php?title=Kirk-Othmer_Encyclopedia_of_Chemical_Technology&action=edit&redlink=1)*.* [*John Wiley & Sons*](https://en.wikipedia.org/wiki/John_Wiley_%26_Sons)*. pp. 1–36.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1002/0471238961.0301041303011818.a01.pub3*](https://doi.org/10.1002%2F0471238961.0301041303011818.a01.pub3)*.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-471-23896-6*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-471-23896-6)*.*

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