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**Nickel**

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This article is about the chemical element. For coins known as "nickels" and other uses, see [Nickel (disambiguation)](https://en.wikipedia.org/wiki/Nickel_(disambiguation)).

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| --- | --- |
| Nickel,  28Ni | |
| [A pitted and lumpy piece of nickel, with the top surface cut flat](https://en.wikipedia.org/wiki/File:Nickel_chunk.jpg) | |
| **General properties** | |
| **Appearance** | lustrous, metallic, and silver with a gold tinge |
| [**Standard atomic weight**](https://en.wikipedia.org/wiki/Standard_atomic_weight) **(*A*r, standard)** | 58.6934(4)[[1]](https://en.wikipedia.org/wiki/Nickel#cite_note-CIAAW2016-1) |
| **Nickel 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 | [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) | | – ↑ **Ni** ↓ [Pd](https://en.wikipedia.org/wiki/Palladium) | | [cobalt](https://en.wikipedia.org/wiki/Cobalt) ← **nickel** → [copper](https://en.wikipedia.org/wiki/Copper) | | | | |
| [**Atomic number**](https://en.wikipedia.org/wiki/Atomic_number)(*Z*) | 28 |
| [**Group**](https://en.wikipedia.org/wiki/Group_(periodic_table)) | [group 10](https://en.wikipedia.org/wiki/Group_10_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)] 3d8 4s2 *or* [Ar] 3d9 4s1 |
| Electrons per shell | 2, 8, 16, 2 *or* 2, 8, 17, 1 |
| **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) | 1728 [K](https://en.wikipedia.org/wiki/Kelvin) ​(1455 °C, ​2651 °F) |
| [**Boiling point**](https://en.wikipedia.org/wiki/Boiling_point) | 3003 K ​(2730 °C, ​4946 °F) |
| [**Density**](https://en.wikipedia.org/wiki/Density)(near r.t.) | 8.908 g/cm3 |
| when liquid (at m.p.) | 7.81 g/cm3 |
| [**Heat of fusion**](https://en.wikipedia.org/wiki/Enthalpy_of_fusion) | 17.48 [kJ/mol](https://en.wikipedia.org/wiki/Kilojoule_per_mole) |
| [**Heat of vaporization**](https://en.wikipedia.org/wiki/Enthalpy_of_vaporization) | 379 kJ/mol |
| [**Molar heat capacity**](https://en.wikipedia.org/wiki/Molar_heat_capacity) | 26.07 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) | 1783 | 1950 | 2154 | 2410 | 2741 | 3184 | | |
| **Atomic properties** | |
| [**Oxidation states**](https://en.wikipedia.org/wiki/Oxidation_state) | −2, −1, +1,[[2]](https://en.wikipedia.org/wiki/Nickel#cite_note-2) **+2**, +3, +4,[[3]](https://en.wikipedia.org/wiki/Nickel#cite_note-3) (a mildly [basic](https://en.wikipedia.org/wiki/Base_(chemistry)) oxide) |
| [**Electronegativity**](https://en.wikipedia.org/wiki/Electronegativity) | Pauling scale: 1.91 |
| [**Ionization energies**](https://en.wikipedia.org/wiki/Ionization_energy) | * 1st: 737.1 kJ/mol * 2nd: 1753.0 kJ/mol * 3rd: 3395 kJ/mol * ([more](https://en.wikipedia.org/wiki/Molar_ionization_energies_of_the_elements#nickel)) |
| [**Atomic radius**](https://en.wikipedia.org/wiki/Atomic_radius) | empirical: 124 [pm](https://en.wikipedia.org/wiki/Picometre) |
| [**Covalent radius**](https://en.wikipedia.org/wiki/Covalent_radius) | 124±4 pm |
| [**Van der Waals radius**](https://en.wikipedia.org/wiki/Van_der_Waals_radius) | 163 pm |
| [Color lines in a spectral range](https://en.wikipedia.org/wiki/File:Nickel_spectrum_visible.png)  [**Spectral lines**](https://en.wikipedia.org/wiki/Spectral_line) **of nickel** | |
| **Other properties** | |
| [**Crystal structure**](https://en.wikipedia.org/wiki/Crystal_structure) | ​[face-centered cubic](https://en.wikipedia.org/wiki/Cubic_crystal_system) (fcc)  [Face-centered cubic crystal structure for nickel](https://en.wikipedia.org/wiki/File:Cubic-face-centered.svg) |
| [**Speed of sound**](https://en.wikipedia.org/wiki/Speed_of_sound)thin rod | 4900 m/s (at r.t.) |
| [**Thermal expansion**](https://en.wikipedia.org/wiki/Coefficient_of_thermal_expansion) | 13.4 µm/(m·K) (at 25 °C) |
| [**Thermal conductivity**](https://en.wikipedia.org/wiki/Thermal_conductivity) | 90.9 W/(m·K) |
| [**Electrical resistivity**](https://en.wikipedia.org/wiki/Electrical_resistivity_and_conductivity) | 69.3 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) | 200 GPa |
| [**Shear modulus**](https://en.wikipedia.org/wiki/Shear_modulus) | 76 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) | 4.0 |
| [**Vickers hardness**](https://en.wikipedia.org/wiki/Vickers_hardness_test) | 638 MPa |
| [**Brinell hardness**](https://en.wikipedia.org/wiki/Brinell_hardness_test) | 667–1600 MPa |
| [**CAS Number**](https://en.wikipedia.org/wiki/CAS_Registry_Number) | 7440-02-0 |
| **History** | |
| [**Discovery**](https://en.wikipedia.org/wiki/Timeline_of_chemical_element_discoveries) **and first isolation** | [Axel Fredrik Cronstedt](https://en.wikipedia.org/wiki/Axel_Fredrik_Cronstedt) (1751) |
| **Main** [**isotopes of nickel**](https://en.wikipedia.org/wiki/Isotopes_of_nickel) | |
| |  |  |  |  |  | | --- | --- | --- | --- | --- | | [**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) | | **58Ni** | 68.077% | [stable](https://en.wikipedia.org/wiki/Stable_isotope) | | | | **59Ni** | [trace](https://en.wikipedia.org/wiki/Trace_radioisotope) | 7.6×104 y | [ε](https://en.wikipedia.org/wiki/Electron_capture) | [59Co](https://en.wikipedia.org/wiki/Cobalt-59) | | **60Ni** | 26.223% | stable | | | | **61Ni** | 1.140% | stable | | | | **62Ni** | 3.635% | stable | | | | **63Ni** | [syn](https://en.wikipedia.org/wiki/Synthetic_radioisotope) | 100 y | [β−](https://en.wikipedia.org/wiki/Beta_decay) | [63Cu](https://en.wikipedia.org/wiki/Copper-63) | | **64Ni** | 0.926% | stable | | | | |
| * [view](https://en.wikipedia.org/wiki/Template:Infobox_nickel) * [talk](https://en.wikipedia.org/wiki/Template_talk:Infobox_nickel) * [edit](https://en.wikipedia.org/w/index.php?title=Template:Infobox_nickel&action=edit)   | [references](https://en.wikipedia.org/wiki/List_of_data_references_for_chemical_elements) | |

**Nickel** is a [chemical element](https://en.wikipedia.org/wiki/Chemical_element) with symbol **Ni** and [atomic number](https://en.wikipedia.org/wiki/Atomic_number) 28. It is a silvery-white lustrous [metal](https://en.wikipedia.org/wiki/Metal) with a slight golden tinge. Nickel belongs to the [transition metals](https://en.wikipedia.org/wiki/Transition_metal) and is hard and [ductile](https://en.wikipedia.org/wiki/Ductility). Pure nickel, [powdered](https://en.wikipedia.org/wiki/Pulverization) to maximize the reactive [surface area](https://en.wikipedia.org/wiki/Surface_area), shows a significant chemical activity, but larger pieces are slow to react with air under [standard conditions](https://en.wikipedia.org/wiki/Standard_conditions_for_temperature_and_pressure) because an oxide layer forms on the surface and prevents further corrosion ([passivation](https://en.wikipedia.org/wiki/Passivation_(chemistry))). Even so, pure [native](https://en.wikipedia.org/wiki/Native_metal) nickel is found in Earth's crust only in tiny amounts, usually in [ultramafic rocks](https://en.wikipedia.org/wiki/Ultramafic_rock),[[6]](https://en.wikipedia.org/wiki/Nickel#cite_note-6)[[7]](https://en.wikipedia.org/wiki/Nickel#cite_note-7) and in the interiors of larger [nickel–iron meteorites](https://en.wikipedia.org/wiki/Iron_meteorite) that were not exposed to oxygen when outside Earth's atmosphere.

Meteoric nickel is found in combination with [iron](https://en.wikipedia.org/wiki/Iron), a reflection of the origin of those elements as major end products of [supernova nucleosynthesis](https://en.wikipedia.org/wiki/Supernova_nucleosynthesis). An iron–nickel mixture is thought to compose Earth's [inner core](https://en.wikipedia.org/wiki/Inner_core).[[8]](https://en.wikipedia.org/wiki/Nickel#cite_note-8)

Use of nickel (as a natural [meteoric](https://en.wikipedia.org/wiki/Meteoric_iron) nickel–iron alloy) has been traced as far back as 3500 BCE. Nickel was first isolated and classified as a chemical element in 1751 by [Axel Fredrik Cronstedt](https://en.wikipedia.org/wiki/Axel_Fredrik_Cronstedt), who initially mistook the [ore](https://en.wikipedia.org/wiki/Ore) for a [copper](https://en.wikipedia.org/wiki/Copper) [mineral](https://en.wikipedia.org/wiki/Mineral), in the cobalt mines of [Los, Hälsingland, Sweden](https://en.wikipedia.org/wiki/Los,_Sweden). The element's name comes from a mischievous sprite of German miner mythology, Nickel (similar to [Old Nick](https://en.wikipedia.org/wiki/Devil_in_Christianity#Christian_tradition)), who personified the fact that copper-nickel ores resisted refinement into copper. An economically important source of nickel is the [iron](https://en.wikipedia.org/wiki/Iron) ore [limonite](https://en.wikipedia.org/wiki/Limonite), which often contains 1–2% nickel. Nickel's other important ore minerals include [pentlandite](https://en.wikipedia.org/wiki/Pentlandite) and a mixture of Ni-rich natural silicates known as [garnierite](https://en.wikipedia.org/wiki/Garnierite). Major production sites include the [Sudbury region](https://en.wikipedia.org/wiki/Sudbury_Basin) in [Canada](https://en.wikipedia.org/wiki/Canada) (which is thought to be of [meteoric](https://en.wikipedia.org/wiki/Meteorite) origin), [New Caledonia](https://en.wikipedia.org/wiki/New_Caledonia) in the [Pacific](https://en.wikipedia.org/wiki/Pacific_Ocean), and [Norilsk](https://en.wikipedia.org/wiki/Norilsk) in [Russia](https://en.wikipedia.org/wiki/Russia).

Nickel is slowly [oxidized](https://en.wikipedia.org/wiki/Oxidation) by air at room temperature and is considered corrosion-resistant. Historically, it has been used for plating iron and [brass](https://en.wikipedia.org/wiki/Brass), coating chemistry equipment, and manufacturing certain [alloys](https://en.wikipedia.org/wiki/Alloy) that retain a high silvery polish, such as [German silver](https://en.wikipedia.org/wiki/Nickel_silver). About 9% of world nickel production is still used for corrosion-resistant nickel plating. Nickel-plated objects sometimes provoke [nickel allergy](https://en.wikipedia.org/wiki/Nickel_allergy). Nickel has been widely used in [coins](https://en.wikipedia.org/wiki/Coins), though its rising price has led to some replacement with cheaper metals in recent years.

Nickel is one of four elements (the others are [iron](https://en.wikipedia.org/wiki/Iron), [cobalt](https://en.wikipedia.org/wiki/Cobalt), and [gadolinium](https://en.wikipedia.org/wiki/Gadolinium))[[9]](https://en.wikipedia.org/wiki/Nickel#cite_note-CoeySkumryev1999-9) that are [ferromagnetic](https://en.wikipedia.org/wiki/Ferromagnetic) at approximately room temperature. [Alnico](https://en.wikipedia.org/wiki/Alnico) permanent [magnets](https://en.wikipedia.org/wiki/Magnets) based partly on nickel are of intermediate strength between iron-based permanent magnets and [rare-earth magnets](https://en.wikipedia.org/wiki/Rare-earth_magnet). The metal is valuable in modern times chiefly in [alloys](https://en.wikipedia.org/wiki/Alloy); about 68% of world production is used in stainless steel. A further 10% is used for nickel-based and copper-based alloys, 7% for alloy steels, 3% in foundries, 9% in plating and 4% in other applications, including the fast-growing battery sector.[[10]](https://en.wikipedia.org/wiki/Nickel#cite_note-:7-10) As a compound, nickel has a number of niche chemical manufacturing uses, such as a [catalyst for hydrogenation](https://en.wikipedia.org/wiki/Raney_nickel), cathodes for batteries, pigments and metal surface treatments.[[11]](https://en.wikipedia.org/wiki/Nickel#cite_note-11) Nickel is an essential nutrient for some microorganisms and plants that have [enzymes](https://en.wikipedia.org/wiki/Enzymes) with nickel as an [active site](https://en.wikipedia.org/wiki/Active_site).

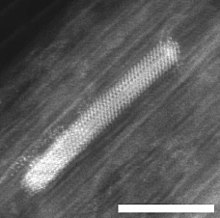


**Contents**

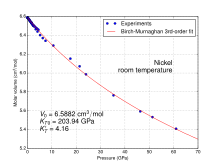
* [1 Properties](https://en.wikipedia.org/wiki/Nickel#Properties)
  + [1.1 Atomic and physical properties](https://en.wikipedia.org/wiki/Nickel#Atomic_and_physical_properties)
    - [1.1.1 Electron configuration dispute](https://en.wikipedia.org/wiki/Nickel#Electron_configuration_dispute)
  + [1.2 Isotopes](https://en.wikipedia.org/wiki/Nickel#Isotopes)
  + [1.3 Occurrence](https://en.wikipedia.org/wiki/Nickel#Occurrence)
* [2 Compounds](https://en.wikipedia.org/wiki/Nickel#Compounds)
  + [2.1 Nickel(0)](https://en.wikipedia.org/wiki/Nickel#Nickel(0))
  + [2.2 Nickel(I)](https://en.wikipedia.org/wiki/Nickel#Nickel(I))
  + [2.3 Nickel(II)](https://en.wikipedia.org/wiki/Nickel#Nickel(II))
  + [2.4 Nickel(III) and (IV)](https://en.wikipedia.org/wiki/Nickel#Nickel(III)_and_(IV))
* [3 History](https://en.wikipedia.org/wiki/Nickel#History)
* [4 Coinage](https://en.wikipedia.org/wiki/Nickel#Coinage)
  + [4.1 Canada](https://en.wikipedia.org/wiki/Nickel#Canada)
  + [4.2 Switzerland](https://en.wikipedia.org/wiki/Nickel#Switzerland)
  + [4.3 United Kingdom](https://en.wikipedia.org/wiki/Nickel#United_Kingdom)
  + [4.4 United States](https://en.wikipedia.org/wiki/Nickel#United_States)
  + [4.5 Current use](https://en.wikipedia.org/wiki/Nickel#Current_use)
* [5 World production](https://en.wikipedia.org/wiki/Nickel#World_production)
* [6 Extraction and purification](https://en.wikipedia.org/wiki/Nickel#Extraction_and_purification)
  + [6.1 Electrorefining](https://en.wikipedia.org/wiki/Nickel#Electrorefining)
  + [6.2 Mond process](https://en.wikipedia.org/wiki/Nickel#Mond_process)
  + [6.3 Metal value](https://en.wikipedia.org/wiki/Nickel#Metal_value)
* [7 Applications](https://en.wikipedia.org/wiki/Nickel#Applications)
* [8 Biological role](https://en.wikipedia.org/wiki/Nickel#Biological_role)
* [9 Toxicity](https://en.wikipedia.org/wiki/Nickel#Toxicity)
* [10 References](https://en.wikipedia.org/wiki/Nickel#References)
* [11 External links](https://en.wikipedia.org/wiki/Nickel#External_links)

**Properties**

**Atomic and physical properties**

[](https://en.wikipedia.org/wiki/File:Ni@CNT2.jpg)

[Electron micrograph](https://en.wikipedia.org/wiki/Transmission_electron_microscopy) of a Ni nanocrystal inside a single wall [carbon nanotube](https://en.wikipedia.org/wiki/Carbon_nanotube); scale bar 5 nm.[[12]](https://en.wikipedia.org/wiki/Nickel#cite_note-12)

[](https://en.wikipedia.org/wiki/File:Nickel-pV.svg)

Molar volume vs. pressure at room temperature

Nickel is a silvery-white metal with a slight golden tinge that takes a high polish. It is one of only four elements that are magnetic at or near room temperature, the others being iron, [cobalt](https://en.wikipedia.org/wiki/Cobalt) and [gadolinium](https://en.wikipedia.org/wiki/Gadolinium). Its [Curie temperature](https://en.wikipedia.org/wiki/Curie_temperature) is 355 °C (671 °F), meaning that bulk nickel is non-magnetic above this temperature.[[13]](https://en.wikipedia.org/wiki/Nickel#cite_note-13) The unit cell of nickel is a [face-centered cube](https://en.wikipedia.org/wiki/Cubic_crystal_system) with the lattice parameter of 0.352 nm, giving an [atomic radius](https://en.wikipedia.org/wiki/Atomic_radius) of 0.124 nm. This crystal structure is stable to pressures of at least 70 GPa. Nickel belongs to the transition metals and is hard and [ductile](https://en.wikipedia.org/wiki/Ductility).

**Electron configuration dispute**

The nickel atom has two [electron configurations](https://en.wikipedia.org/wiki/Electron_configuration), [Ar] 3d8 4s2 and [Ar] 3d9 4s1, which are very close in energy – the symbol [Ar] refers to the [argon](https://en.wikipedia.org/wiki/Argon)-like core structure. There is some disagreement on which configuration has the lowest energy.[[14]](https://en.wikipedia.org/wiki/Nickel#cite_note-Scerri-14) Chemistry textbooks quote the electron configuration of nickel as [Ar] 4s2 3d8,[[15]](https://en.wikipedia.org/wiki/Nickel#cite_note-15) which can also be written [Ar] 3d8 4s2.[[16]](https://en.wikipedia.org/wiki/Nickel#cite_note-16) This configuration agrees with the [Madelung energy ordering rule](https://en.wikipedia.org/wiki/Madelung_rule), which predicts that 4s is filled before 3d. It is supported by the experimental fact that the lowest energy state of the nickel atom is a 3d8 4s2 energy level, specifically the 3d8(3F) 4s2 3F, *J* = 4 level.[[17]](https://en.wikipedia.org/wiki/Nickel#cite_note-NIST-17)

However, each of these two configurations splits into several energy levels due to [fine structure](https://en.wikipedia.org/wiki/Fine_structure),[[17]](https://en.wikipedia.org/wiki/Nickel#cite_note-NIST-17) and the two sets of energy levels overlap. The average energy of states with configuration [Ar] 3d9 4s1 is actually lower than the average energy of states with configuration [Ar] 3d8 4s2. For this reason, the research literature on atomic calculations quotes the ground state configuration of nickel as [Ar] 3d9 4s1.[[14]](https://en.wikipedia.org/wiki/Nickel#cite_note-Scerri-14)

**Isotopes**

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

The isotopes of nickel range in [atomic weight](https://en.wikipedia.org/wiki/Atomic_weight) from 48 [u](https://en.wikipedia.org/wiki/Atomic_mass_unit) (48  
Ni) to 78 u (78  
Ni).

Naturally occurring nickel is composed of five stable [isotopes](https://en.wikipedia.org/wiki/Isotope); 58  
Ni, 60  
Ni, 61  
Ni, 62  
Ni and 64  
Ni, with 58  
Ni being the most abundant (68.077% [natural abundance](https://en.wikipedia.org/wiki/Natural_abundance)). Isotopes heavier than 62  
Ni cannot be formed by [nuclear fusion](https://en.wikipedia.org/wiki/Nuclear_fusion) without losing energy.

[Nickel-62](https://en.wikipedia.org/wiki/Nickel-62) has the highest mean [nuclear binding energy](https://en.wikipedia.org/wiki/Nuclear_binding_energy) per nucleon of any [nuclide](https://en.wikipedia.org/wiki/Nuclide), at 8.7946 MeV/nucleon.[[18]](https://en.wikipedia.org/wiki/Nickel#cite_note-18) Its binding energy is greater than both [56  
Fe](https://en.wikipedia.org/wiki/Iron-56) and [58  
Fe](https://en.wikipedia.org/wiki/Iron-58), more abundant elements often incorrectly cited as having the most tightly-bound nuclides.[[19]](https://en.wikipedia.org/wiki/Nickel#cite_note-aip1995-19) Although this would seem to predict nickel-62 as the most abundant heavy element in the universe, the relatively high rate of photodisintegration of nickel in stellar interiors causes iron to be by far the most abundant.[[19]](https://en.wikipedia.org/wiki/Nickel#cite_note-aip1995-19)

Stable isotope nickel-60 is the daughter product of the [extinct radionuclide](https://en.wikipedia.org/wiki/Extinct_radionuclide) [60  
Fe](https://en.wikipedia.org/wiki/Iron-60), which decays with a half-life of 2.6 million years. Because 60  
Fe has such a long half-life, its persistence in materials in the [solar system](https://en.wikipedia.org/wiki/Solar_system) may generate observable variations in the isotopic composition of 60  
Ni. Therefore, the abundance of 60  
Ni present in extraterrestrial material may provide insight into the origin of the solar system and its early history.

Some 18 nickel [radioisotopes](https://en.wikipedia.org/wiki/Radioisotope) have been characterised, the most stable being 59  
Ni with a [half-life](https://en.wikipedia.org/wiki/Half-life) of 76,000 years, 63  
Ni with 100 years, and 56  
Ni with 6 days. All of the remaining [radioactive](https://en.wikipedia.org/wiki/Radioactive) isotopes have half-lives that are less than 60 hours and the majority of these have half-lives that are less than 30 seconds. This element also has one [meta state](https://en.wikipedia.org/wiki/Meta_state).[[20]](https://en.wikipedia.org/wiki/Nickel#cite_note-Audi-20)

Radioactive nickel-56 is produced by the [silicon burning process](https://en.wikipedia.org/wiki/Silicon_burning_process) and later set free in large quantities during [type Ia](https://en.wikipedia.org/wiki/Type_IIn) [supernovae](https://en.wikipedia.org/wiki/Supernova). The shape of the [light curve](https://en.wikipedia.org/wiki/Light_curve) of these supernovae at intermediate to late-times corresponds to the decay via [electron capture](https://en.wikipedia.org/wiki/Electron_capture) of nickel-56 to [cobalt](https://en.wikipedia.org/wiki/Cobalt)-56 and ultimately to iron-56.[[21]](https://en.wikipedia.org/wiki/Nickel#cite_note-Nucleos-21) Nickel-59 is a long-lived [cosmogenic](https://en.wikipedia.org/wiki/Cosmogenic_nuclide) [radionuclide](https://en.wikipedia.org/wiki/Radionuclide) with a half-life of 76,000 years. 59  
Ni has found many applications in [isotope geology](https://en.wikipedia.org/wiki/Isotope_geology). 59  
Ni has been used to date the terrestrial age of [meteorites](https://en.wikipedia.org/wiki/Meteorite) and to determine abundances of extraterrestrial dust in ice and [sediment](https://en.wikipedia.org/wiki/Sediment). Nickel-78's half-life was recently measured at 110 milliseconds, and is believed an important isotope in [supernova nucleosynthesis](https://en.wikipedia.org/wiki/Supernova_nucleosynthesis) of elements heavier than iron.[[22]](https://en.wikipedia.org/wiki/Nickel#cite_note-22) The nuclide 48Ni, discovered in 1999, is the most proton-rich heavy element isotope known. With 28 [protons](https://en.wikipedia.org/wiki/Proton) and 20 [neutrons](https://en.wikipedia.org/wiki/Neutron) 48Ni is "[double magic](https://en.wikipedia.org/wiki/Double_magic)", as is 78  
Ni with 28 protons and 50 neutrons. Both are therefore unusually stable for nuclides with so large a proton-neutron imbalance.[[20]](https://en.wikipedia.org/wiki/Nickel#cite_note-Audi-20)[[23]](https://en.wikipedia.org/wiki/Nickel#cite_note-23)

**Occurrence**

See also: [Ore genesis](https://en.wikipedia.org/wiki/Ore_genesis) and [Category:Nickel minerals](https://en.wikipedia.org/wiki/Category:Nickel_minerals)

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

[Widmanstätten pattern](https://en.wikipedia.org/wiki/Widmanst%C3%A4tten_pattern) showing the two forms of nickel-iron, kamacite and taenite, in an octahedrite meteorite

On Earth, nickel occurs most often in combination with [sulfur](https://en.wikipedia.org/wiki/Sulfur) and iron in [pentlandite](https://en.wikipedia.org/wiki/Pentlandite), with [sulfur](https://en.wikipedia.org/wiki/Sulfur) in [millerite](https://en.wikipedia.org/wiki/Millerite), with [arsenic](https://en.wikipedia.org/wiki/Arsenic) in the mineral [nickeline](https://en.wikipedia.org/wiki/Nickeline), and with arsenic and [sulfur](https://en.wikipedia.org/wiki/Sulfur) in nickel [galena](https://en.wikipedia.org/wiki/Galena).[[24]](https://en.wikipedia.org/wiki/Nickel#cite_note-24) Nickel is commonly found in [iron meteorites](https://en.wikipedia.org/wiki/Iron_meteorite) as the alloys [kamacite](https://en.wikipedia.org/wiki/Kamacite) and [taenite](https://en.wikipedia.org/wiki/Taenite).

The bulk of the nickel is mined from two types of [ore](https://en.wikipedia.org/wiki/Ore) deposits. The first is [laterite](https://en.wikipedia.org/wiki/Laterite), where the principal ore mineral mixtures are nickeliferous [limonite](https://en.wikipedia.org/wiki/Limonite), (Fe,Ni)O(OH), and [garnierite](https://en.wikipedia.org/wiki/Garnierite) (a mixture of various hydrous nickel and nickel-rich silicates). The second is magmatic [sulfide](https://en.wikipedia.org/wiki/Sulfide) deposits, where the principal ore mineral is [pentlandite](https://en.wikipedia.org/wiki/Pentlandite): (Ni,Fe)  
9S  
8.

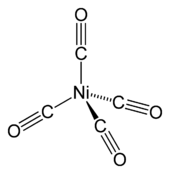
[Australia](https://en.wikipedia.org/wiki/Australia) and [New Caledonia](https://en.wikipedia.org/wiki/New_Caledonia) have the biggest estimate reserves (45% all together).[[25]](https://en.wikipedia.org/wiki/Nickel#cite_note-USGSCS2012-25)

Identified land-based resources throughout the world averaging 1% nickel or greater comprise at least 130 million tons of nickel (about the double of known reserves). About 60% is in [laterites](https://en.wikipedia.org/wiki/Laterites) and 40% in sulfide deposits.[[25]](https://en.wikipedia.org/wiki/Nickel#cite_note-USGSCS2012-25)

On [geophysical](https://en.wikipedia.org/wiki/Geophysics) evidence, most of the nickel on Earth is believed to be in the Earth's [outer](https://en.wikipedia.org/wiki/Outer_core) and [inner cores](https://en.wikipedia.org/wiki/Inner_core). [Kamacite](https://en.wikipedia.org/wiki/Kamacite) and [taenite](https://en.wikipedia.org/wiki/Taenite) are naturally occurring [alloys](https://en.wikipedia.org/wiki/Alloy) of iron and nickel. For kamacite, the alloy is usually in the proportion of 90:10 to 95:5, although impurities (such as [cobalt](https://en.wikipedia.org/wiki/Cobalt) or [carbon](https://en.wikipedia.org/wiki/Carbon)) may be present, while for taenite the nickel content is between 20% and 65%. Kamacite and taenite are also found in [nickel iron meteorites](https://en.wikipedia.org/wiki/Nickel_iron_meteorite).[[26]](https://en.wikipedia.org/wiki/Nickel#cite_note-26)

**Compounds**

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

[](https://en.wikipedia.org/wiki/File:Nickel-carbonyl-2D.png)

Tetracarbonyl nickel

The most common [oxidation state](https://en.wikipedia.org/wiki/Oxidation_state) of nickel is +2, but compounds of Ni0, Ni+, and Ni3+ are well known, and the exotic oxidation states Ni2−, Ni1−, and Ni4+ have been produced and studied.[[27]](https://en.wikipedia.org/wiki/Nickel#cite_note-Greenwood-27)

**Nickel(0)**

[Nickel tetracarbonyl](https://en.wikipedia.org/wiki/Nickel_tetracarbonyl) (Ni(CO)  
4), discovered by [Ludwig Mond](https://en.wikipedia.org/wiki/Ludwig_Mond),[[28]](https://en.wikipedia.org/wiki/Nickel#cite_note-MondNa-28) is a volatile, highly toxic liquid at room temperature. On heating, the complex decomposes back to nickel and carbon monoxide:

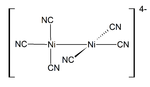
Ni(CO)  
4 ⇌ Ni + 4 CO

This behavior is exploited in the [Mond process](https://en.wikipedia.org/wiki/Mond_process) for purifying nickel, as described above. The related nickel(0) complex [bis(cyclooctadiene)nickel(0)](https://en.wikipedia.org/wiki/Bis(cyclooctadiene)nickel(0)) is a useful catalyst in [organonickel chemistry](https://en.wikipedia.org/wiki/Organonickel_chemistry) because the [cyclooctadiene](https://en.wikipedia.org/wiki/1,5-Cyclooctadiene) (or *cod*) ligands are easily displaced.

**Nickel(I)**

Nickel(I) complexes are uncommon, but one example is the tetrahedral complex NiBr(PPh3)3. Many nickel(I) complexes feature Ni-Ni bonding, such as the dark red [diamagnetic](https://en.wikipedia.org/wiki/Diamagnetic) K  
4[Ni  
2(CN)  
6] prepared by reduction of K  
2[Ni  
2(CN)  
6] with [sodium amalgam](https://en.wikipedia.org/wiki/Sodium_amalgam). This compound is oxidised in water, liberating H  
2.[[29]](https://en.wikipedia.org/wiki/Nickel#cite_note-InorgChemH-29)

It is thought that the nickel(I) oxidation state is important to nickel-containing enzymes, such as [[NiFe]-hydrogenase](https://en.wikipedia.org/wiki/NiFe_Hydrogenase), which catalyzes the reversible reduction of [protons](https://en.wikipedia.org/wiki/Protons) to H  
2.[[30]](https://en.wikipedia.org/wiki/Nickel#cite_note-Housecroft_4th-30)

[](https://en.wikipedia.org/wiki/File:Structure_of_hexacyanodinickelate(I)_ion.png)

Structure of [Ni  
2(CN)  
6]4−  
ion[[29]](https://en.wikipedia.org/wiki/Nickel#cite_note-InorgChemH-29)

**Nickel(II)**

[](https://en.wikipedia.org/wiki/File:Color_of_various_Ni(II)_complexes_in_aqueous_solution.jpg)

Color of various Ni(II) complexes in aqueous solution. From left to right, [Ni(NH  
3)  
6]2+  
, [Ni([C2H4(NH2)2](https://en.wikipedia.org/wiki/Ethylenediamine))]2+, [NiCl  
4]2−  
, [Ni(H  
2O)  
6]2+

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

Crystals of [hydrated](https://en.wikipedia.org/wiki/Water_of_hydration) [nickel sulfate](https://en.wikipedia.org/wiki/Nickel_sulfate).

Nickel(II) forms compounds with all common anions, including [sulfide](https://en.wikipedia.org/wiki/Nickel_sulfide), [sulfate](https://en.wikipedia.org/wiki/Nickel_sulfate), carbonate, hydroxide, carboxylates, and halides. [Nickel(II) sulfate](https://en.wikipedia.org/wiki/Nickel(II)_sulfate) is produced in large quantities by dissolving nickel metal or oxides in sulfuric acid, forming both a hexa- and heptahydrates[[31]](https://en.wikipedia.org/wiki/Nickel#cite_note-31) useful for [electroplating](https://en.wikipedia.org/wiki/Nickel_electroplating) nickel. Common salts of nickel, such as the chloride, nitrate, and sulfate, dissolve in water to give green solutions of the [metal aquo complex](https://en.wikipedia.org/wiki/Metal_aquo_complex) [Ni(H  
2O)  
6]2+  
.

The four halides form nickel compounds, which are solids with molecules that feature octahedral Ni centres. [Nickel(II) chloride](https://en.wikipedia.org/wiki/Nickel(II)_chloride) is most common, and its behavior is illustrative of the other halides. Nickel(II) chloride is produced by dissolving nickel or its oxide in [hydrochloric acid](https://en.wikipedia.org/wiki/Hydrochloric_acid). It is usually encountered as the green hexahydrate, the formula of which is usually written NiCl2•6H2O. When dissolved in water, this salt forms the [metal aquo complex](https://en.wikipedia.org/wiki/Metal_aquo_complex) [Ni(H  
2O)  
6]2+  
. Dehydration of NiCl2•6H2O gives the yellow anhydrous NiCl  
2.

Some tetracoordinate nickel(II) complexes, e.g. [bis(triphenylphosphine)nickel chloride](https://en.wikipedia.org/wiki/Bis(triphenylphosphine)nickel_chloride), exist both in tetrahedral and square planar geometries. The tetrahedral complexes are [paramagnetic](https://en.wikipedia.org/wiki/Paramagnetic), whereas the square planar complexes are [diamagnetic](https://en.wikipedia.org/wiki/Diamagnetic). In having properties of magnetic equilibrium and formation of octahedral complexes, they contrast with the divalent complexes of the heavier group 10 metals, palladium(II) and platinum(II), which form only square-planar geometry.[[27]](https://en.wikipedia.org/wiki/Nickel#cite_note-Greenwood-27)

[Nickelocene](https://en.wikipedia.org/wiki/Nickelocene) is known; it has an [electron count](https://en.wikipedia.org/wiki/Electron_counting) of 20, making it relatively unstable.

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

Nickel(III) antimonide

**Nickel(III) and (IV)**

Numerous Ni(III) compounds are known, with the first such examples being Nickel(III) trihalophosphines (NiIII(PPh3)X3).[[32]](https://en.wikipedia.org/wiki/Nickel#cite_note-Jensen-32) Further, Ni(III) forms simple salts with fluoride[[33]](https://en.wikipedia.org/wiki/Nickel#cite_note-Ni(III)F-33) or [oxide](https://en.wikipedia.org/wiki/Nickel(III)_oxide) ions. Ni(III) can be stabilized by σ-donor ligands such as [thiols](https://en.wikipedia.org/wiki/Thiol) and [phosphines](https://en.wikipedia.org/wiki/Phosphine).[[29]](https://en.wikipedia.org/wiki/Nickel#cite_note-InorgChemH-29)

Ni(IV) is present in the mixed oxide BaNiO  
3, while Ni(III) is present in [nickel oxide hydroxide](https://en.wikipedia.org/wiki/Nickel_oxide_hydroxide), which is used as the [cathode](https://en.wikipedia.org/wiki/Cathode) in many [rechargeable batteries](https://en.wikipedia.org/wiki/Rechargeable_battery), including [nickel-cadmium](https://en.wikipedia.org/wiki/Nickel-cadmium), [nickel-iron](https://en.wikipedia.org/wiki/Nickel-iron_battery), [nickel hydrogen](https://en.wikipedia.org/wiki/Nickel_hydrogen_battery), and [nickel-metal hydride](https://en.wikipedia.org/wiki/Nickel-metal_hydride_battery), and used by certain manufacturers in [Li-ion](https://en.wikipedia.org/wiki/Li-ion) batteries.[[34]](https://en.wikipedia.org/wiki/Nickel#cite_note-34) Ni(IV) remains a rare oxidation state of nickel and very few compounds are known to date.[[35]](https://en.wikipedia.org/wiki/Nickel#cite_note-35)[[36]](https://en.wikipedia.org/wiki/Nickel#cite_note-36)[[37]](https://en.wikipedia.org/wiki/Nickel#cite_note-NiIV_Science-37)[[38]](https://en.wikipedia.org/wiki/Nickel#cite_note-NiIV_dap-38)

**History**

Because the ores of nickel are easily mistaken for ores of silver, understanding of this metal and its use dates to relatively recent times. However, the unintentional use of nickel is ancient, and can be traced back as far as 3500 BCE. [Bronzes](https://en.wikipedia.org/wiki/Bronze) from what is now Syria have been found to contain as much as 2% nickel.[[39]](https://en.wikipedia.org/wiki/Nickel#cite_note-39) Some ancient Chinese manuscripts suggest that "white copper" ([cupronickel](https://en.wikipedia.org/wiki/Cupronickel), known as *baitong*) was used there between 1700 and 1400 BCE. This Paktong white copper was exported to Britain as early as the 17th century, but the nickel content of this alloy was not discovered until 1822.[[40]](https://en.wikipedia.org/wiki/Nickel#cite_note-McNeil-40) Coins of nickel-copper alloy were minted by the Bactrian kings [Agathocles](https://en.wikipedia.org/wiki/Agathocles_of_Bactria), [Euthydemus II](https://en.wikipedia.org/wiki/Euthydemus_II) and [Pantaleon](https://en.wikipedia.org/wiki/Pantaleon) in the 2nd Century BCE, possibly out of the Chinese cupronickel.[[41]](https://en.wikipedia.org/wiki/Nickel#cite_note-41)

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

nickeline/niccolite

In medieval Germany, a red mineral was found in the [Erzgebirge](https://en.wikipedia.org/wiki/Erzgebirge) (Ore Mountains) that resembled copper ore. However, when miners were unable to extract any copper from it, they blamed a mischievous sprite of German mythology, Nickel (similar to [*Old Nick*](https://en.wikipedia.org/wiki/Christian_teaching_about_the_Devil)), for besetting the copper. They called this ore *Kupfernickel* from the German *Kupfer* for copper.[[42]](https://en.wikipedia.org/wiki/Nickel#cite_note-42)[[43]](https://en.wikipedia.org/wiki/Nickel#cite_note-JEC-I-43)[[44]](https://en.wikipedia.org/wiki/Nickel#cite_note-JEC-II-44)[[45]](https://en.wikipedia.org/wiki/Nickel#cite_note-JEC-III-45) This ore is now known to be [nickeline](https://en.wikipedia.org/wiki/Nickeline), a nickel [arsenide](https://en.wikipedia.org/wiki/Arsenide). In 1751, Baron [Axel Fredrik Cronstedt](https://en.wikipedia.org/wiki/Axel_Fredrik_Cronstedt) tried to extract copper from kupfernickel at a [cobalt](https://en.wikipedia.org/wiki/Cobalt) mine in the [Swedish](https://en.wikipedia.org/wiki/Sweden) village of [Los](https://en.wikipedia.org/wiki/Los,_Sweden), and instead produced a white metal that he named after the spirit that had given its name to the mineral, nickel.[[46]](https://en.wikipedia.org/wiki/Nickel#cite_note-46) In modern German, Kupfernickel or Kupfer-Nickel designates the alloy [cupronickel](https://en.wikipedia.org/wiki/Cupronickel).

Originally, the only source for nickel was the rare Kupfernickel. Beginning in 1824, nickel was obtained as a byproduct of [cobalt blue](https://en.wikipedia.org/wiki/Cobalt_blue) production. The first large-scale smelting of nickel began in Norway in 1848 from nickel-rich [pyrrhotite](https://en.wikipedia.org/wiki/Pyrrhotite). The introduction of nickel in steel production in 1889 increased the demand for nickel, and the nickel deposits of [New Caledonia](https://en.wikipedia.org/wiki/New_Caledonia), discovered in 1865, provided most of the world's supply between 1875 and 1915. The discovery of the large deposits in the [Sudbury Basin](https://en.wikipedia.org/wiki/Sudbury_Basin), Canada in 1883, in [Norilsk-Talnakh](https://en.wikipedia.org/wiki/Norilsk), Russia in 1920, and in the [Merensky Reef](https://en.wikipedia.org/wiki/Merensky_Reef), South Africa in 1924, made large-scale production of nickel possible.[[40]](https://en.wikipedia.org/wiki/Nickel#cite_note-McNeil-40)

**Coinage**

[](https://en.wikipedia.org/wiki/File:Nickel2.jpg)

[Dutch coins](https://en.wikipedia.org/wiki/Dutch_guilder) made of pure nickel

Aside from the aforementioned Bactrian coins, nickel was not a component of coins until the mid-19th century.

**Canada**

[99.9% nickel five-cent coins](https://en.wikipedia.org/wiki/Nickel_(Canadian_coin)) were struck in Canada (the world's largest nickel producer at the time) during non-war years from 1922–1981; the metal content made these coins magnetic.[[47]](https://en.wikipedia.org/wiki/Nickel#cite_note-47) During the wartime period 1942–45, most or all nickel was removed from Canadian and U.S. coins to save it for manufacturing armor.[[43]](https://en.wikipedia.org/wiki/Nickel#cite_note-JEC-I-43)[[48]](https://en.wikipedia.org/wiki/Nickel#cite_note-48) Canada used 99.9% nickel from 1968 in its higher-value coins until 2000.

**Switzerland**

Coins of nearly pure nickel were first used in 1881 in Switzerland.[[49]](https://en.wikipedia.org/wiki/Nickel#cite_note-anna-49)

**United Kingdom**

Birmingham forged nickel coins in about 1833 for trading in Malaya.[[50]](https://en.wikipedia.org/wiki/Nickel#cite_note-50)

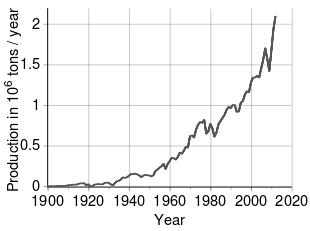
**United States**

In the United States, the term "nickel" or "nick" originally applied to the copper-nickel [Flying Eagle cent](https://en.wikipedia.org/wiki/Flying_Eagle_cent), which replaced copper with 12% nickel 1857–58, then the [Indian Head cent](https://en.wikipedia.org/wiki/Indian_Head_cent) of the same alloy from 1859–1864. Still later, in 1865, the term designated the [three-cent nickel](https://en.wikipedia.org/wiki/Three-cent_piece_(United_States_coin)), with nickel increased to 25%. In 1866, the [five-cent shield nickel](https://en.wikipedia.org/wiki/Nickel_(United_States_coin)#Shield_nickel_(1866–1883)) (25% nickel, 75% copper) appropriated the designation. Along with the alloy proportion, this term has been used to the present in the United States.

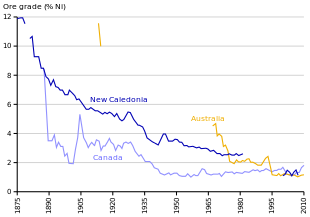
**Current use**

In the 21st century, the high price of nickel has led to some replacement of the metal in coins around the world. Coins still made with nickel alloys include one- and two-[euro coins](https://en.wikipedia.org/wiki/Euro_coins), 5¢, 10¢, 25¢ and 50¢ [U.S. coins](https://en.wikipedia.org/wiki/Coins_of_the_United_States_dollar), and 20p, 50p, £1 and £2 [UK coins](https://en.wikipedia.org/wiki/Coins_of_the_pound_sterling). Nickel-alloy in 5p and 10p UK coins was replaced with nickel-plated steel began in 2012, causing allergy problems for some people and public controversy.[[49]](https://en.wikipedia.org/wiki/Nickel#cite_note-anna-49)

**World production**

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

Time trend of nickel production[[51]](https://en.wikipedia.org/wiki/Nickel#cite_note-51)

[](https://en.wikipedia.org/w/index.php?title=File:Evolution_minerai_nickel.svg&lang=en)

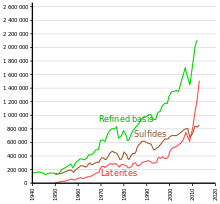
Nickel ores grade evolution in some leading nickel producing countries.

Around 2 million tonnes of nickel are produced annually worldwide.[[52]](https://en.wikipedia.org/wiki/Nickel#cite_note-52) The [Philippines](https://en.wikipedia.org/wiki/Philippines), [Indonesia](https://en.wikipedia.org/wiki/Indonesia), [Russia](https://en.wikipedia.org/wiki/Russia), [Canada](https://en.wikipedia.org/wiki/Canada) and [Australia](https://en.wikipedia.org/wiki/Australia) are the world's largest producers of nickel, as reported by the [US Geological Survey](https://en.wikipedia.org/wiki/US_Geological_Survey).[[25]](https://en.wikipedia.org/wiki/Nickel#cite_note-USGSCS2012-25) The largest deposits of nickel in non-Russian Europe are located in [Finland](https://en.wikipedia.org/wiki/Finland) and [Greece](https://en.wikipedia.org/wiki/Greece). Identified land-based resources averaging 1% nickel or greater contain at least 130 million tons of nickel. About 60% is in laterites and 40% is in sulfide deposits. In addition, extensive deep-sea resources of nickel are in manganese crusts and nodules covering large areas of the ocean floor, particularly in the Pacific Ocean.[[53]](https://en.wikipedia.org/wiki/Nickel#cite_note-usgs1-53)

The one locality in the United States where nickel has been profitably mined is [Riddle, Oregon](https://en.wikipedia.org/wiki/Riddle,_Oregon), where several square miles of nickel-bearing [garnierite](https://en.wikipedia.org/wiki/Garnierite) surface deposits are located. The mine closed in 1987.[[54]](https://en.wikipedia.org/wiki/Nickel#cite_note-54)[[55]](https://en.wikipedia.org/wiki/Nickel#cite_note-55) The [Eagle mine project](https://en.wikipedia.org/wiki/Eagle_mine_project) is a new nickel mine in [Michigan](https://en.wikipedia.org/wiki/Michigan)'s [upper peninsula](https://en.wikipedia.org/wiki/Upper_Peninsula_of_Michigan). Construction was completed in 2013, and operations began in the third quarter of 2014.[[56]](https://en.wikipedia.org/wiki/Nickel#cite_note-eagle-56) In the first full year of operation, Eagle Mine produced 18,000 tonnes.[[56]](https://en.wikipedia.org/wiki/Nickel#cite_note-eagle-56)

| **Mine production and reserves (in metric tons)** | **2016 (estimated)**[**[57]**](https://en.wikipedia.org/wiki/Nickel#cite_note-usgs5-57) | **2015**[**[57]**](https://en.wikipedia.org/wiki/Nickel#cite_note-usgs5-57) | **2014**[**[58]**](https://en.wikipedia.org/wiki/Nickel#cite_note-usgs4-58) | **2013**[**[59]**](https://en.wikipedia.org/wiki/Nickel#cite_note-usgs3-59) | **2012**[**[60]**](https://en.wikipedia.org/wiki/Nickel#cite_note-usgs2-60) | **2011**[**[53]**](https://en.wikipedia.org/wiki/Nickel#cite_note-usgs1-53) | **Reserves**[**[57]**](https://en.wikipedia.org/wiki/Nickel#cite_note-usgs5-57) |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Australia | 206,000 | 222,000 | 245,000 | 234,000 | 246,000 | 215,000 | 19,000,000 |
| Botswana | NA | NA | NA | NA | NA | 26,000 | NA |
| Brazil | 142,000 | 160,000 | 102,000 | 138,000 | 139,000 | 209,000 | 10,000,000 |
| Canada | 255,000 | 235,000 | 235,000 | 223,000 | 205,000 | 220,000 | 2,900,000 |
| China | 90,000 | 92,900 | 100,000 | 95,000 | 93,300 | 89,800 | 2,500,000 |
| Colombia | 36,800 | 40,400 | 81,000 | 75,000 | 84,000 | 76,000 | 1,100,000 |
| Cuba | 56,000 | 56,400 | 50,400 | 66,000 | 68,200 | 71,000 | 5,500,000 |
| Dominican Republic | NA | NA | NA | 15,800 | 15,200 | 21,700 | NA |
| Guatemala | 58,600 | 52,400 | 38,400 | NA | NA | NA | 1,800,000 |
| Indonesia | 168,500 | 130,000 | 177,000 | 440,000 | 228,000 | 290,000 | 4,500,000 |
| Madagascar | 48,000 | 45,500 | 40,300 | 29,300 | 8,250 | 5,900 | 1,600,000 |
| New Caledonia | 205,000 | 186,000 | 178,000 | 164,000 | 132,000 | 131,000 | 6,700,000 |
| Philippines | 500,000 | 554,000 | 523,000 | 446,000 | 424,000 | 270,000 | 4,800,000 |
| Russia | 256,000 | 269,000 | 239,000 | 275,000 | 255,000 | 267,000 | 7,600,000 |
| South Africa | 50,000 | 56,700 | 55,000 | 51,200 | 45,900 | 44,000 | 3,700,000 |
| United States | 25,000 | 27,200 | 4,300 | NA | NA | NA | 160,000 |
| Other countries | 150,000 | 157,000 | 377,000 | 377,000 | 273,000 | 103,000 | 6,500,000 |
| World total (rounded) | 2,250,000 | 2,280,000 | 2,450,000 | 2,630,000 | 2,220,000 | 1,940,000 | 78,000,000 |

**Extraction and purification**

[](https://en.wikipedia.org/w/index.php?title=File:Nickel_extraction.svg&lang=en)

Evolution of the annual nickel extraction, according to ores.

Nickel is obtained through [extractive metallurgy](https://en.wikipedia.org/wiki/Extractive_metallurgy): it is extracted from the ore by conventional roasting and reduction processes that yield a metal of greater than 75% purity. In many [stainless steel](https://en.wikipedia.org/wiki/Stainless_steel) applications, 75% pure nickel can be used without further purification, depending on the impurities.

Traditionally, most sulfide ores have been processed using [pyrometallurgical](https://en.wikipedia.org/wiki/Pyrometallurgical) techniques to produce a [matte](https://en.wikipedia.org/wiki/Matte_(metallurgy)) for further refining. Recent advances in [hydrometallurgical techniques](https://en.wikipedia.org/wiki/Hydrometallurgy) resulted in significantly purer metallic nickel product. Most sulfide deposits have traditionally been processed by concentration through a [froth flotation](https://en.wikipedia.org/wiki/Froth_flotation) process followed by [pyrometallurgical](https://en.wikipedia.org/wiki/Pyrometallurgical) extraction. In hydrometallurgical processes, nickel sulfide ores are concentrated with flotation (differential flotation if Ni/Fe ratio is too low) and then smelted. The nickel matte is further processed with the [Sherritt-Gordon process](https://en.wikipedia.org/wiki/Cobalt_extraction_techniques#Recovery_from_nickel-cobalt_sulfide_concentrates_(Sherritt_process)). First, copper is removed by adding [hydrogen sulfide](https://en.wikipedia.org/wiki/Hydrogen_sulfide), leaving a concentrate of cobalt and nickel. Then, solvent extraction is used to separate the cobalt and nickel, with the final nickel content greater than 99%.

[](https://en.wikipedia.org/wiki/File:Nickel_electrolytic_and_1cm3_cube.jpg)

[Electrolytically refined](https://en.wikipedia.org/wiki/Electrolysis) nickel nodule, with green, crystallized nickel-electrolyte salts visible in the pores.

**Electrorefining**

A second common refining process is leaching the metal matte into a nickel salt solution, followed by the electro-winning of the nickel from solution by plating it onto a cathode as electrolytic nickel.

**Mond process**

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

Highly purified nickel spheres made by the [Mond process](https://en.wikipedia.org/wiki/Mond_process).

Main article: [Mond process](https://en.wikipedia.org/wiki/Mond_process)

The purest metal is obtained from nickel oxide by the [Mond process](https://en.wikipedia.org/wiki/Mond_process), which achieves a purity of greater than 99.99%.[[61]](https://en.wikipedia.org/wiki/Nickel#cite_note-61) The process was patented by Ludwig Mond and has been in industrial use since before the beginning of the 20th century. In this process, nickel is reacted with [carbon monoxide](https://en.wikipedia.org/wiki/Carbon_monoxide) in the presence of a sulfur catalyst at around 40–80 °C to form [nickel carbonyl](https://en.wikipedia.org/wiki/Nickel_carbonyl). Iron gives [iron pentacarbonyl](https://en.wikipedia.org/wiki/Iron_pentacarbonyl), too, but this reaction is slow. If necessary, the nickel may be separated by distillation. [Dicobalt octacarbonyl](https://en.wikipedia.org/wiki/Dicobalt_octacarbonyl) is also formed in nickel distillation as a by-product, but it decomposes to [tetracobalt dodecacarbonyl](https://en.wikipedia.org/wiki/Tetracobalt_dodecacarbonyl) at the reaction temperature to give a non-volatile solid.[[62]](https://en.wikipedia.org/wiki/Nickel#cite_note-ullmann-1-62)

Nickel is obtained from nickel carbonyl by one of two processes. It may be passed through a large chamber at high temperatures in which tens of thousands of nickel spheres, called pellets, are constantly stirred. The carbonyl decomposes and deposits pure nickel onto the nickel spheres. In the alternate process, nickel carbonyl is decomposed in a smaller chamber at 230 °C to create a fine nickel powder. The byproduct carbon monoxide is recirculated and reused. The highly pure nickel product is known as "carbonyl nickel".[[63]](https://en.wikipedia.org/wiki/Nickel#cite_note-63)

**Metal value**

The market price of nickel surged throughout 2006 and the early months of 2007; as of April 5, 2007, the metal was trading at [US](https://en.wikipedia.org/wiki/United_States_dollar)$52,300/[tonne](https://en.wikipedia.org/wiki/Tonne) or $1.47/oz.[[64]](https://en.wikipedia.org/wiki/Nickel#cite_note-LME-64) The price subsequently fell dramatically, and as of September 2017, the metal was trading at $11,000/tonne, or $0.31/oz.[[65]](https://en.wikipedia.org/wiki/Nickel#cite_note-65)

The [US nickel coin](https://en.wikipedia.org/wiki/Nickel_(United_States_coin)) contains 0.04 ounces (1.1 g) of nickel, which at the April 2007 price was worth 6.5 cents, along with 3.75 grams of copper worth about 3 cents, with a total metal value of more than 9 cents. Since the face value of a nickel is 5 cents, this made it an attractive target for melting by people wanting to sell the metals at a profit. However, the [United States Mint](https://en.wikipedia.org/wiki/United_States_Mint), in anticipation of this practice, implemented new interim rules on December 14, 2006, subject to public comment for 30 days, which criminalized the melting and export of cents and nickels.[[66]](https://en.wikipedia.org/wiki/Nickel#cite_note-66) Violators can be punished with a fine of up to $10,000 and/or imprisoned for a maximum of five years.

As of September 19, 2013, the melt value of a U.S. nickel (copper and nickel included) is $0.045, which is 90% of the face value.[[67]](https://en.wikipedia.org/wiki/Nickel#cite_note-67)

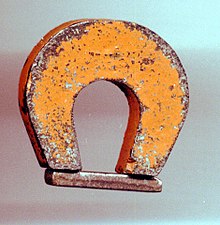
**Applications**

[](https://en.wikipedia.org/wiki/File:Turbinenschaufel_RB199.jpg)

Nickel superalloy jet engine ([RB199](https://en.wikipedia.org/wiki/RB199)) turbine blade

The global production of nickel is presently used as follows: 68% in stainless steel; 10% in nonferrous [alloys](https://en.wikipedia.org/wiki/Alloy); 9% in [electroplating](https://en.wikipedia.org/wiki/Electroplating); 7% in alloy steel; 3% in foundries; and 4% other uses (including batteries).[[10]](https://en.wikipedia.org/wiki/Nickel#cite_note-:7-10)

Nickel is used in many specific and recognizable industrial and consumer products, including [stainless steel](https://en.wikipedia.org/wiki/Stainless_steel), [alnico](https://en.wikipedia.org/wiki/Alnico) magnets, coinage, [rechargeable batteries](https://en.wikipedia.org/wiki/Rechargeable_battery), electric guitar strings, microphone capsules, plating on plumbing fixtures,[[68]](https://en.wikipedia.org/wiki/Nickel#cite_note-68) and special alloys such as [permalloy](https://en.wikipedia.org/wiki/Permalloy), [elinvar](https://en.wikipedia.org/wiki/Elinvar), and [invar](https://en.wikipedia.org/wiki/Invar). It is used for plating and as a green tint in glass. Nickel is preeminently an alloy metal, and its chief use is in nickel steels and nickel cast irons, in which it typically increases the tensile strength, toughness, and elastic limit. It is widely used in many other alloys, including nickel brasses and bronzes and alloys with copper, chromium, aluminium, lead, cobalt, silver, and gold ([Inconel](https://en.wikipedia.org/wiki/Inconel), [Incoloy](https://en.wikipedia.org/wiki/Incoloy), [Monel](https://en.wikipedia.org/wiki/Monel), [Nimonic](https://en.wikipedia.org/wiki/Nimonic)).[[69]](https://en.wikipedia.org/wiki/Nickel#cite_note-69)

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

A "horseshoe magnet" made of [alnico](https://en.wikipedia.org/wiki/Alnico) nickel alloy.

Because it is resistant to corrosion, nickel was occasionally used as a substitute for decorative silver. Nickel was also occasionally used in some countries after 1859 as a cheap coinage metal (see above), but in the later years of the 20th century was replaced by cheaper [stainless steel](https://en.wikipedia.org/wiki/Stainless_steel) (i.e., iron) alloys, except in the United States and Canada.

Nickel is an excellent alloying agent for certain precious metals and is used in the [fire assay](https://en.wikipedia.org/wiki/Metallurgical_assay) as a collector of [platinum group elements](https://en.wikipedia.org/wiki/Platinum_group) (PGE). As such, nickel is capable of fully collecting all six PGE elements from ores, and of partially collecting gold. High-throughput nickel mines may also engage in PGE recovery (primarily [platinum](https://en.wikipedia.org/wiki/Platinum) and [palladium](https://en.wikipedia.org/wiki/Palladium)); examples are Norilsk in Russia and the Sudbury Basin in Canada.

[Nickel foam](https://en.wikipedia.org/wiki/Metal_foam) or nickel mesh is used in [gas diffusion electrodes](https://en.wikipedia.org/wiki/Gas_diffusion_electrode) for [alkaline fuel cells](https://en.wikipedia.org/wiki/Alkaline_fuel_cell).[[70]](https://en.wikipedia.org/wiki/Nickel#cite_note-70)[[71]](https://en.wikipedia.org/wiki/Nickel#cite_note-71)

Nickel and its alloys are frequently used as catalysts for [hydrogenation](https://en.wikipedia.org/wiki/Hydrogenation) reactions. [Raney nickel](https://en.wikipedia.org/wiki/Raney_nickel), a finely divided nickel-aluminium alloy, is one common form, though related catalysts are also used, including Raney-type catalysts.

Nickel is a naturally magnetostrictive material, meaning that, in the presence of a [magnetic field](https://en.wikipedia.org/wiki/Magnetic_field), the material undergoes a small change in length.[[72]](https://en.wikipedia.org/wiki/Nickel#cite_note-72)[[73]](https://en.wikipedia.org/wiki/Nickel#cite_note-73) The [magnetostriction](https://en.wikipedia.org/wiki/Magnetostriction) of nickel is on the order of 50 ppm and is negative, indicating that it contracts.

Nickel is used as a binder in the cemented [tungsten carbide](https://en.wikipedia.org/wiki/Tungsten_carbide) or hardmetal industry and used in proportions of 6% to 12% by weight. Nickel makes the tungsten carbide magnetic and adds corrosion-resistance to the cemented parts, although the hardness is less than those with a cobalt binder.[[74]](https://en.wikipedia.org/wiki/Nickel#cite_note-74)

63  
Ni, with its [half-life](https://en.wikipedia.org/wiki/Half-life) of 100.1 years, is useful in [krytron](https://en.wikipedia.org/wiki/Krytron) devices as a [beta particle](https://en.wikipedia.org/wiki/Beta_particle) (high-speed [electron](https://en.wikipedia.org/wiki/Electron)) emitter to make [ionization](https://en.wikipedia.org/wiki/Ionization) by the keep-alive electrode more reliable.[[75]](https://en.wikipedia.org/wiki/Nickel#cite_note-75)

Around 27% of all nickel production is destined for engineering, 10% for building and construction, 14% for tubular products, 20% for metal goods, 14% for transport, 11% for electronic goods, and 5% for other uses.[[10]](https://en.wikipedia.org/wiki/Nickel#cite_note-:7-10)

**Biological role**

Although not recognized until the 1970s, nickel is known to play an important role in the biology of some plants, [eubacteria](https://en.wikipedia.org/wiki/Eubacteria), [archaebacteria](https://en.wikipedia.org/wiki/Archaebacteria), and [fungi](https://en.wikipedia.org/wiki/Fungi).[[76]](https://en.wikipedia.org/wiki/Nickel#cite_note-Sigel-76)[[77]](https://en.wikipedia.org/wiki/Nickel#cite_note-Sydor-77)[[78]](https://en.wikipedia.org/wiki/Nickel#cite_note-78) Nickel enzymes such as [urease](https://en.wikipedia.org/wiki/Urease) are considered virulence factors in some organisms.[[79]](https://en.wikipedia.org/wiki/Nickel#cite_note-79)[[80]](https://en.wikipedia.org/wiki/Nickel#cite_note-80) Urease catalyzes the hydrolysis of [urea](https://en.wikipedia.org/wiki/Urea) to form ammonia and carbamate.[[77]](https://en.wikipedia.org/wiki/Nickel#cite_note-Sydor-77)[[76]](https://en.wikipedia.org/wiki/Nickel#cite_note-Sigel-76) The [NiFe hydrogenases](https://en.wikipedia.org/wiki/NiFe_hydrogenase) can catalyze the oxidation of H  
2 to form protons and electrons, and can also catalyze the reverse reaction, the reduction of protons to form hydrogen gas.[[77]](https://en.wikipedia.org/wiki/Nickel#cite_note-Sydor-77)[[76]](https://en.wikipedia.org/wiki/Nickel#cite_note-Sigel-76) A nickel-tetrapyrrole coenzyme, [cofactor F430](https://en.wikipedia.org/wiki/Cofactor_F430), is present in methyl [coenzyme M](https://en.wikipedia.org/wiki/Coenzyme_M) reductase, which can catalyze the formation of methane, or the reverse reaction, in [methanogenic](https://en.wikipedia.org/wiki/Methanogen) [archaea](https://en.wikipedia.org/wiki/Archaea).[[81]](https://en.wikipedia.org/wiki/Nickel#cite_note-81) One of the carbon monoxide dehydrogenase enzymes consists of an Fe-Ni-S cluster.[[82]](https://en.wikipedia.org/wiki/Nickel#cite_note-82) Other nickel-bearing enzymes include a rare bacterial class of [superoxide dismutase](https://en.wikipedia.org/wiki/Superoxide_dismutase)[[83]](https://en.wikipedia.org/wiki/Nickel#cite_note-83) and [glyoxalase I](https://en.wikipedia.org/wiki/Glyoxalase_I) enzymes in bacteria and several parasitic eukaryotic [trypanosomal](https://en.wikipedia.org/wiki/Trypanosomatid) parasites[[84]](https://en.wikipedia.org/wiki/Nickel#cite_note-84) (in higher organisms, including yeast and mammals, this enzyme contains divalent Zn2+).[[85]](https://en.wikipedia.org/wiki/Nickel#cite_note-aronsson_1978-85)[[86]](https://en.wikipedia.org/wiki/Nickel#cite_note-ridderstroem_1996-86)[[87]](https://en.wikipedia.org/wiki/Nickel#cite_note-87)[[88]](https://en.wikipedia.org/wiki/Nickel#cite_note-88)[[89]](https://en.wikipedia.org/wiki/Nickel#cite_note-89)

Dietary nickel may affect human health through infections by nickel-dependent bacteria, but it is also possible that nickel is an essential nutrient for bacteria residing in the large intestine, in effect functioning as a [prebiotic](https://en.wikipedia.org/wiki/Prebiotic_(nutrition)).[[90]](https://en.wikipedia.org/wiki/Nickel#cite_note-90) The U.S. Institute of Medicine has not confirmed that nickel is an essential nutrient for humans, so neither a [Recommended Dietary Allowance](https://en.wikipedia.org/wiki/Recommended_Dietary_Allowance) (RDA) nor an Adequate Intake have been established. The [Tolerable Upper Intake Level](https://en.wikipedia.org/wiki/Tolerable_upper_intake_levels) of dietary nickel is 1000 µg/day as soluble nickel salts. Dietary intake is estimated at 70 to 100 µg/day, with less than 10% absorbed. What is absorbed is excreted in urine.[[91]](https://en.wikipedia.org/wiki/Nickel#cite_note-91) Relatively large amounts of nickel – comparable to the estimated average ingestion above – [leach](https://en.wikipedia.org/wiki/Leaching_(chemistry)) into food cooked in stainless steel. For example, the amount of nickel leached after 10 cooking cycles into one serving of tomato sauce averages 88 µg.[[92]](https://en.wikipedia.org/wiki/Nickel#cite_note-92)[[93]](https://en.wikipedia.org/wiki/Nickel#cite_note-93)

Nickel released from [Siberian Traps](https://en.wikipedia.org/wiki/Siberian_Traps) volcanic eruptions is suspected of assisting the growth of [*Methanosarcina*](https://en.wikipedia.org/wiki/Methanosarcina), a genus of euryarchaeote archaea that produced methane during the [Permian–Triassic extinction event](https://en.wikipedia.org/wiki/Permian%E2%80%93Triassic_extinction_event), the biggest extinction event on record.[[94]](https://en.wikipedia.org/wiki/Nickel#cite_note-94)

**Toxicity**

Further information: [Nickel allergy](https://en.wikipedia.org/wiki/Nickel_allergy)

|  |  |
| --- | --- |
| Nickel | |
| **Hazards** | |
| [GHS pictograms](https://en.wikipedia.org/wiki/GHS_hazard_pictograms) | [The exclamation-mark pictogram in the Globally Harmonized System of Classification and Labelling of Chemicals (GHS)](https://en.wikipedia.org/wiki/File:GHS-pictogram-exclam.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) |
| [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, H351, H372, H412 |
| [GHS precautionary statements](https://en.wikipedia.org/wiki/GHS_precautionary_statements) | P273, P280, P314, P333+313[[95]](https://en.wikipedia.org/wiki/Nickel#cite_note-95) |
| [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) |

The major source of nickel exposure is oral consumption, as nickel is essential to plants.[[96]](https://en.wikipedia.org/wiki/Nickel#cite_note-96) Nickel is found naturally in both food and water, and may be increased by human [pollution](https://en.wikipedia.org/wiki/Pollution). For example, nickel-plated [faucets](https://en.wikipedia.org/wiki/Faucet) may contaminate water and soil; [mining](https://en.wikipedia.org/wiki/Mining) and smelting may dump nickel into [waste-water](https://en.wikipedia.org/wiki/Waste-water); nickel–steel [alloy](https://en.wikipedia.org/wiki/Alloy) cookware and nickel-pigmented dishes may release nickel into food. The atmosphere may be polluted by nickel ore refining and [fossil fuel](https://en.wikipedia.org/wiki/Fossil_fuel) combustion. Humans may absorb nickel directly from [tobacco smoke](https://en.wikipedia.org/wiki/Tobacco_smoke) and skin contact with jewelry, [shampoos](https://en.wikipedia.org/wiki/Shampoo), detergents, and [coins](https://en.wikipedia.org/wiki/Coin). A less-common form of chronic exposure is through [hemodialysis](https://en.wikipedia.org/wiki/Hemodialysis) as traces of nickel ions may be absorbed into the plasma from the [chelating](https://en.wikipedia.org/wiki/Chelating) action of [albumin](https://en.wikipedia.org/wiki/Albumin).

The average daily exposure does not pose a threat to human health. Most of the nickel absorbed every day by humans is removed by the kidneys and passed out of the body through urine or is eliminated through the gastrointestinal tract without being absorbed. Nickel is not a cumulative poison, but larger doses or chronic inhalation exposure may be toxic, even [carcinogenic](https://en.wikipedia.org/wiki/Carcinogen), and constitute an [occupational hazard](https://en.wikipedia.org/wiki/Occupational_hazard).[[97]](https://en.wikipedia.org/wiki/Nickel#cite_note-97)

Nickel compounds are classified as human carcinogens[[98]](https://en.wikipedia.org/wiki/Nickel#cite_note-:0-98)[[99]](https://en.wikipedia.org/wiki/Nickel#cite_note-:1-99)[[100]](https://en.wikipedia.org/wiki/Nickel#cite_note-:2-100)[[101]](https://en.wikipedia.org/wiki/Nickel#cite_note-:3-101) based on increased respiratory cancer risks observed in epidemiological studies of sulfidic ore refinery workers.[[102]](https://en.wikipedia.org/wiki/Nickel#cite_note-:4-102) This is supported by the positive results of the NTP bioassays with Ni sub-sulfide and Ni oxide in rats and mice.[[103]](https://en.wikipedia.org/wiki/Nickel#cite_note-:5-103)[[104]](https://en.wikipedia.org/wiki/Nickel#cite_note-104) The human and animal data consistently indicate a lack of carcinogenicity via the oral route of exposure and limit the carcinogenicity of nickel compounds to respiratory tumours after inhalation.[[105]](https://en.wikipedia.org/wiki/Nickel#cite_note-105)[[106]](https://en.wikipedia.org/wiki/Nickel#cite_note-106) Nickel metal is classified as a suspect carcinogen;[[98]](https://en.wikipedia.org/wiki/Nickel#cite_note-:0-98)[[99]](https://en.wikipedia.org/wiki/Nickel#cite_note-:1-99)[[100]](https://en.wikipedia.org/wiki/Nickel#cite_note-:2-100) there is consistency between the absence of increased respiratory cancer risks in workers predominantly exposed to metallic nickel[[102]](https://en.wikipedia.org/wiki/Nickel#cite_note-:4-102) and the lack of respiratory tumours in a rat lifetime inhalation carcinogenicity study with nickel metal powder.[[107]](https://en.wikipedia.org/wiki/Nickel#cite_note-:6-107) In the rodent inhalation studies with various nickel compounds and nickel metal, increased lung inflammations with and without bronchial lymph node hyperplasia or fibrosis were observed.[[101]](https://en.wikipedia.org/wiki/Nickel#cite_note-:3-101)[[103]](https://en.wikipedia.org/wiki/Nickel#cite_note-:5-103)[[107]](https://en.wikipedia.org/wiki/Nickel#cite_note-:6-107)[[108]](https://en.wikipedia.org/wiki/Nickel#cite_note-108) In rat studies, oral ingestion of water-soluble nickel salts can trigger perinatal mortality effects in pregnant animals.[[109]](https://en.wikipedia.org/wiki/Nickel#cite_note-109) Whether these effects are relevant to humans is unclear as epidemiological studies of highly exposed female workers have not shown adverse developmental toxicity effects.[[110]](https://en.wikipedia.org/wiki/Nickel#cite_note-110)[[111]](https://en.wikipedia.org/wiki/Nickel#cite_note-111)[[112]](https://en.wikipedia.org/wiki/Nickel#cite_note-112)[[113]](https://en.wikipedia.org/wiki/Nickel#cite_note-113)

People can be exposed to nickel in the workplace by inhalation, ingestion, and contact with skin or eye. The [Occupational Safety and Health Administration](https://en.wikipedia.org/wiki/Occupational_Safety_and_Health_Administration) (OSHA) has set the legal limit ([permissible exposure limit](https://en.wikipedia.org/wiki/Permissible_exposure_limit)) for the workplace at 1 mg/m3 per 8-hour workday, excluding nickel carbonyl. The [National Institute for Occupational Safety and Health](https://en.wikipedia.org/wiki/National_Institute_for_Occupational_Safety_and_Health) (NIOSH) specifies the [recommended exposure limit](https://en.wikipedia.org/wiki/Recommended_exposure_limit) (REL) of 0.015 mg/m3 per 8-hour workday. At 10 mg/m3, nickel is [immediately dangerous to life and health](https://en.wikipedia.org/wiki/IDLH).[[114]](https://en.wikipedia.org/wiki/Nickel#cite_note-114) [Nickel carbonyl](https://en.wikipedia.org/wiki/Nickel_carbonyl) [Ni(CO)  
4] is an extremely toxic gas. The toxicity of metal carbonyls is a function of both the toxicity of the metal and the off-gassing of [carbon monoxide](https://en.wikipedia.org/wiki/Carbon_monoxide) from the carbonyl functional groups; nickel carbonyl is also explosive in air.[[115]](https://en.wikipedia.org/wiki/Nickel#cite_note-115)[[116]](https://en.wikipedia.org/wiki/Nickel#cite_note-116)

[Sensitized](https://en.wikipedia.org/wiki/Sensitization_(immunology)) individuals may show a skin contact [allergy to nickel](https://en.wikipedia.org/wiki/Nickel_allergy_(nickel_allergic_contact_dermatitis)) known as a contact [dermatitis](https://en.wikipedia.org/wiki/Dermatitis). Highly sensitized individuals may also react to foods with high nickel content.[[117]](https://en.wikipedia.org/wiki/Nickel#cite_note-aad-117) Sensitivity to nickel may also be present in patients with [pompholyx](https://en.wikipedia.org/wiki/Dyshidrosis). Nickel is the top confirmed contact allergen worldwide, partly due to its use in jewelry for [pierced ears](https://en.wikipedia.org/wiki/Pierced_ear).[[118]](https://en.wikipedia.org/wiki/Nickel#cite_note-118) Nickel allergies affecting pierced ears are often marked by itchy, red skin. Many earrings are now made without nickel or low-release nickel[[119]](https://en.wikipedia.org/wiki/Nickel#cite_note-119) to address this problem. The amount allowed in products that contact human skin is now regulated by the [European Union](https://en.wikipedia.org/wiki/European_Union). In 2002, researchers found that the nickel released by 1 and 2 Euro coins was far in excess of those standards. This is believed to be the result of a [galvanic](https://en.wikipedia.org/wiki/Galvanization) reaction.[[120]](https://en.wikipedia.org/wiki/Nickel#cite_note-120) Nickel was voted [Allergen of the Year](https://en.wikipedia.org/wiki/Allergen_of_the_Year) in 2008 by the American Contact Dermatitis Society.[[121]](https://en.wikipedia.org/wiki/Nickel#cite_note-121) In August 2015, the American Academy of Dermatology adopted a position statement on the safety of nickel: "Estimates suggest that contact dermatitis, which includes nickel sensitization, accounts for approximately $1.918 billion and affects nearly 72.29 million people."[[117]](https://en.wikipedia.org/wiki/Nickel#cite_note-aad-117)

Reports show that both the nickel-induced activation of hypoxia-inducible factor (HIF-1) and the up-regulation of hypoxia-inducible genes are caused by depletion of intracellular [ascorbate](https://en.wikipedia.org/wiki/Ascorbate). The addition of ascorbate to the culture medium increased the intracellular ascorbate level and reversed both the metal-induced stabilization of HIF-1- and HIF-1α-dependent gene expression.[[122]](https://en.wikipedia.org/wiki/Nickel#cite_note-122)[[123]](https://en.wikipedia.org/wiki/Nickel#cite_note-123)

**References**

 *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)*.*

  *Pfirrmann, Stefan; Limberg, Christian; Herwig, Christian; Stößer, Reinhard; Ziemer, Burkhard (2009). "A Dinuclear Nickel(I) Dinitrogen Complex and its Reduction in Single-Electron Steps". Angewandte Chemie International Edition.* ***48*** *(18): 3357.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1002/anie.200805862*](https://doi.org/10.1002%2Fanie.200805862)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*19322853*](https://www.ncbi.nlm.nih.gov/pubmed/19322853)*.*

  *Carnes, Matthew; Buccella, Daniela; Chen, Judy Y.-C.; Ramirez, Arthur P.; Turro, Nicholas J.; Nuckolls, Colin; Steigerwald, Michael (2009). "A Stable Tetraalkyl Complex of Nickel(IV)". Angewandte Chemie International Edition.* ***48*** *(2): 3384.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1002/anie.200804435*](https://doi.org/10.1002%2Fanie.200804435)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*19021174*](https://www.ncbi.nlm.nih.gov/pubmed/19021174)*.*

  *Carnes, Matthew; Buccella, Daniela; Chen, Judy Y.-C.; Ramirez, Arthur P.; Turro, Nicholas J.; Nuckolls, Colin; Steigerwald, Michael (2009). "A Stable Tetraalkyl Complex of Nickel(IV)". Angewandte Chemie International Edition.* ***48*** *(2): 3384.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1002/anie.200804435*](https://doi.org/10.1002%2Fanie.200804435)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*19021174*](https://www.ncbi.nlm.nih.gov/pubmed/19021174)*.*

  *Pfirrmann, Stefan; Limberg, Christian; Herwig, Christian; Stößer, Reinhard; Ziemer, Burkhard (2009). "A Dinuclear Nickel(I) Dinitrogen Complex and its Reduction in Single-Electron Steps". Angewandte Chemie International Edition.* ***48*** *(18): 3357.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1002/anie.200805862*](https://doi.org/10.1002%2Fanie.200805862)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*19322853*](https://www.ncbi.nlm.nih.gov/pubmed/19322853)*.*

  [*"Nickel – Handbook of Mineralogy"*](http://www.handbookofmineralogy.org/pdfs/nickel.pdf) *(PDF). Handbookofmineralogy.org. Retrieved 2016-03-02.*

  [*"Nickel: Nickel mineral information and data"*](http://www.mindat.org/min-2895.html)*. Mindat.org. Retrieved 2016-03-02.*

  *Stixrude, Lars; Waserman, Evgeny; Cohen, Ronald (November 1997). "Composition and temperature of Earth's inner core". Journal of Geophysical Research.* ***102*** *(B11): 24729–24740.* [*Bibcode*](https://en.wikipedia.org/wiki/Bibcode)*:*[*1997JGR...10224729S*](http://adsabs.harvard.edu/abs/1997JGR...10224729S)*.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1029/97JB02125*](https://doi.org/10.1029%2F97JB02125)*.*

  *Coey, J. M. D.; Skumryev, V.; Gallagher, K. (1999). "Rare-earth metals: Is gadolinium really ferromagnetic?". Nature.* ***401*** *(6748): 35–36.* [*Bibcode*](https://en.wikipedia.org/wiki/Bibcode)*:*[*1999Natur.401...35C*](http://adsabs.harvard.edu/abs/1999Natur.401...35C)*.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1038/43363*](https://doi.org/10.1038%2F43363)*.*

  [*"Nickel Use In Society"*](https://www.nickelinstitute.org/NickelUseInSociety/AboutNickel/FirstAndEndUsesofNickel.aspx)*. Nickel Institute.*

  [*"Nickel Compounds – The Inside Story"*](https://nickelinstitute.org/~/media/Files/MediaCenter/NiCompounds/NI%20Compounds%202015%20v12%20FINAL.ashx?la=en)*. Nickel Institute.*

  *Shiozawa, Hidetsugu; Briones-Leon, Antonio; Domanov, Oleg; Zechner, Georg; et al. (2015).* [*"Nickel clusters embedded in carbon nanotubes as high performance magnets"*](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4602218)*. Scientific Reports.* ***5****: 15033.* [*Bibcode*](https://en.wikipedia.org/wiki/Bibcode)*:*[*2015NatSR...515033S*](http://adsabs.harvard.edu/abs/2015NatSR...515033S)*.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1038/srep15033*](https://doi.org/10.1038%2Fsrep15033)*.* [*PMC*](https://en.wikipedia.org/wiki/PubMed_Central)[*4602218*](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4602218)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*26459370*](https://www.ncbi.nlm.nih.gov/pubmed/26459370)*.*

  *Kittel, Charles (1996). Introduction to Solid State Physics. Wiley. p. 449.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-471-14286-7*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-471-14286-7)*.*

  *Scerri, Eric R. (2007).* [*The periodic table: its story and its significance*](https://books.google.com/?id=SNRdGWCGt1UC&pg=PA239)*. Oxford University Press. pp. 239–240.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-19-530573-9*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-19-530573-9)*.*

  Miessler, G.L. and Tarr, D.A. (1999) *Inorganic Chemistry* 2nd ed., Prentice–Hall. p. 38. [ISBN](https://en.wikipedia.org/wiki/International_Standard_Book_Number) [0138418918](https://en.wikipedia.org/wiki/Special:BookSources/0138418918).

  Petrucci, R.H. et al. (2002) *General Chemistry* 8th ed., Prentice–Hall. p. 950. [ISBN](https://en.wikipedia.org/wiki/International_Standard_Book_Number) [0130143294](https://en.wikipedia.org/wiki/Special:BookSources/0130143294).

  [NIST Atomic Spectrum Database](http://physics.nist.gov/PhysRefData/ASD/levels_form.html) To read the nickel atom levels, type "Ni I" in the Spectrum box and click on Retrieve data.

  [*"The Most Tightly Bound Nuclei"*](http://hyperphysics.phy-astr.gsu.edu/hbase/nucene/nucbin2.html#c1)*. Retrieved November 19, 2008.*

  *Fewell, M. P. (1995). "The atomic nuclide with the highest mean binding energy". American Journal of Physics.* ***63*** *(7): 653.* [*Bibcode*](https://en.wikipedia.org/wiki/Bibcode)*:*[*1995AmJPh..63..653F*](http://adsabs.harvard.edu/abs/1995AmJPh..63..653F)*.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1119/1.17828*](https://doi.org/10.1119%2F1.17828)*.*

  *Audi, Georges; Bersillon, O.; Blachot, J.; Wapstra, A. H. (2003).* [*"The NUBASE Evaluation of Nuclear and Decay Properties"*](http://hal.in2p3.fr/in2p3-00014184)*. Nuclear Physics A.* ***729*** *(1): 3–128.* [*Bibcode*](https://en.wikipedia.org/wiki/Bibcode)*:*[*2003NuPhA.729....3A*](http://adsabs.harvard.edu/abs/2003NuPhA.729....3A)*.* [*CiteSeerX*](https://en.wikipedia.org/wiki/CiteSeerX)[*10.1.1.692.8504*](https://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.692.8504)*.* [*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)*.*

  *Pagel, Bernard Ephraim Julius (1997-09-04). "Further burning stages: evolution of massive stars". Nucleosynthesis and chemical evolution of galaxies. pp. 154–160.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-521-55958-4*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-521-55958-4)*.*

  *Castelvecchi, Davide (April 22, 2005).* [*"Atom Smashers Shed Light on Supernovae, Big Bang"*](http://www.skyandtelescope.com/news/3310246.html?page=1&c=y)*. Retrieved November 19, 2008.*

  *W, P. (October 23, 1999).* [*"Twice-magic metal makes its debut – isotope of nickel"*](https://archive.is/20120524134125/http:/www.findarticles.com/p/articles/mi_m1200/is_17_156/ai_57799535)*.* [*Science News*](https://en.wikipedia.org/wiki/Science_News)*. Archived from* [*the original*](http://www.findarticles.com/p/articles/mi_m1200/is_17_156/ai_57799535) *on May 24, 2012. Retrieved September 29, 2006.*

  [National Pollutant Inventory – Nickel and compounds Fact Sheet](http://www.npi.gov.au/substances/nickel/index.html). Npi.gov.au. Retrieved on January 9, 2012.

  *Kuck, Peter H.* [*"Mineral Commodity Summaries 2012: Nickel"*](http://minerals.usgs.gov/minerals/pubs/commodity/nickel/mcs-2012-nicke.pdf) *(PDF). United States Geological Survey. Retrieved November 19, 2008.*

  *Rasmussen, K. L.; Malvin, D. J.; Wasson, J. T. (1988). "Trace element partitioning between taenite and kamacite – Relationship to the cooling rates of iron meteorites". Meteoritics.* ***23*** *(2): a107–112.* [*Bibcode*](https://en.wikipedia.org/wiki/Bibcode)*:*[*1988Metic..23..107R*](http://adsabs.harvard.edu/abs/1988Metic..23..107R)*.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1111/j.1945-5100.1988.tb00905.x*](https://doi.org/10.1111%2Fj.1945-5100.1988.tb00905.x)*.*

  [*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)*.* [*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)*.*

  *"The Extraction of Nickel from its Ores by the Mond Process". Nature.* ***59*** *(1516): 63–64. 1898.* [*Bibcode*](https://en.wikipedia.org/wiki/Bibcode)*:*[*1898Natur..59...63.*](http://adsabs.harvard.edu/abs/1898Natur..59...63.)*.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1038/059063a0*](https://doi.org/10.1038%2F059063a0)*.*

  *Housecroft, C. E.; Sharpe, A. G. (2008). Inorganic Chemistry (3rd ed.). Prentice Hall. p. 729.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0131755536*](https://en.wikipedia.org/wiki/Special:BookSources/978-0131755536)*.*

  *Housecroft, C. E.; Sharpe, A. G. (2012). Inorganic Chemistry (4th ed.). Prentice Hall. p. 764.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0273742753*](https://en.wikipedia.org/wiki/Special:BookSources/978-0273742753)*.*

  Lascelles, Keith; Morgan, Lindsay G.; Nicholls, David and Beyersmann, Detmar (2005) "Nickel Compounds" in *Ullmann's Encyclopedia of Industrial Chemistry*. Wiley-VCH, Weinheim. [doi](https://en.wikipedia.org/wiki/Digital_object_identifier):[10.1002/14356007.a17\_235.pub2](https://doi.org/10.1002%2F14356007.a17_235.pub2)

  *Jensen, K. A. (1936). "Zur Stereochemie des koordinativ vierwertigen Nickels". Zeitschrift für Anorganische und Allgemeine Chemie.* ***229*** *(3): 265–281.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1002/zaac.19362290304*](https://doi.org/10.1002%2Fzaac.19362290304)*.*

  *Court, T. L.; Dove, M. F. A. (1973). "Fluorine compounds of nickel(III)". Journal of the Chemical Society, Dalton Transactions (19): 1995.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1039/DT9730001995*](https://doi.org/10.1039%2FDT9730001995)*.*

  [*"Imara Corporation Launches; New Li-ion Battery Technology for High-Power Applications"*](http://www.greencarcongress.com/2008/12/imara-corporati.html)*. Green Car Congress. December 18, 2008.*

  *Spokoyny, Alexander M.; Li, Tina C.; Farha, Omar K.; Machan, Charles M.; She, Chunxing; Stern, Charlotte L.; Marks, Tobin J.; Hupp, Joseph T.; Mirkin, Chad A. (28 June 2010). "Electronic Tuning of Nickel-Based Bis(dicarbollide) Redox Shuttles in Dye-Sensitized Solar Cells". Angew. Chem. Int. Ed.* ***49*** *(31): 5339–5343.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1002/anie.201002181*](https://doi.org/10.1002%2Fanie.201002181)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*20586090*](https://www.ncbi.nlm.nih.gov/pubmed/20586090)*.*

  *Hawthorne, M. Frederick (1967). "(3)-1,2-Dicarbollyl Complexes of Nickel(III) and Nickel(IV)". Journal of the American Chemical Society.* ***89*** *(2): 470–471.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1021/ja00978a065*](https://doi.org/10.1021%2Fja00978a065)*.*

  *Camasso, N. M.; Sanford, M. S. (2015). "Design, synthesis, and carbon-heteroatom coupling reactions of organometallic nickel(IV) complexes". Science.* ***347*** *(6227): 1218–20.* [*Bibcode*](https://en.wikipedia.org/wiki/Bibcode)*:*[*2015Sci...347.1218C*](http://adsabs.harvard.edu/abs/2015Sci...347.1218C)*.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1126/science.aaa4526*](https://doi.org/10.1126%2Fscience.aaa4526)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*25766226*](https://www.ncbi.nlm.nih.gov/pubmed/25766226)*.*

  *Baucom, E. I.; Drago, R. S. (1971). "Nickel(II) and nickel(IV) complexes of 2,6-diacetylpyridine dioxime". Journal of the American Chemical Society.* ***93*** *(24): 6469–6475.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1021/ja00753a022*](https://doi.org/10.1021%2Fja00753a022)*.*

  *Rosenberg, Samuel J. (1968).* [*Nickel and Its Alloys*](http://handle.dtic.mil/100.2/ADA381960)*. National Bureau of Standards.*

  *McNeil, Ian (1990). "The Emergence of Nickel". An Encyclopaedia of the History of Technology. Taylor & Francis. pp. 96–100.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-415-01306-2*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-415-01306-2)*.*

  [Joseph Needham](https://en.wikipedia.org/wiki/Joseph_Needham), Ling Wang, Gwei-Djen Lu, [Tsuen-hsuin Tsien](https://en.wikipedia.org/wiki/Tsuen-hsuin_Tsien), Dieter Kuhn, Peter J Golas, [*Science and civilisation in China*](https://books.google.com/books?id=BYixSmXUCuMC&pg=PA237): Cambridge University Press: 1974, [ISBN](https://en.wikipedia.org/wiki/International_Standard_Book_Number) [0-521-08571-3](https://en.wikipedia.org/wiki/Special:BookSources/0-521-08571-3), pp. 237–250

  *Chambers Twentieth Century Dictionary*, p888, W&R Chambers Ltd., 1977.

  *Baldwin, W. H. (1931). "The story of Nickel. I. How "Old Nick's" gnomes were outwitted". Journal of Chemical Education.* ***8*** *(9): 1749.* [*Bibcode*](https://en.wikipedia.org/wiki/Bibcode)*:*[*1931JChEd...8.1749B*](http://adsabs.harvard.edu/abs/1931JChEd...8.1749B)*.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1021/ed008p1749*](https://doi.org/10.1021%2Fed008p1749)*.*

  *Baldwin, W. H. (1931). "The story of Nickel. II. Nickel comes of age". Journal of Chemical Education.* ***8*** *(10): 1954.* [*Bibcode*](https://en.wikipedia.org/wiki/Bibcode)*:*[*1931JChEd...8.1954B*](http://adsabs.harvard.edu/abs/1931JChEd...8.1954B)*.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1021/ed008p1954*](https://doi.org/10.1021%2Fed008p1954)*.*

  *Baldwin, W. H. (1931). "The story of Nickel. III. Ore, matte, and metal". Journal of Chemical Education.* ***8*** *(12): 2325.* [*Bibcode*](https://en.wikipedia.org/wiki/Bibcode)*:*[*1931JChEd...8.2325B*](http://adsabs.harvard.edu/abs/1931JChEd...8.2325B)*.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1021/ed008p2325*](https://doi.org/10.1021%2Fed008p2325)*.*

  [*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*** *(1): 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)*.*

  [*"Industrious, enduring–the 5-cent coin"*](http://www.mint.ca/store/mint/learn/circulation-currency-1100028)*. Royal Canadian Mint. 2008. Retrieved January 10, 2009.*

  *Molloy, Bill (November 8, 2001).* [*"Trends of Nickel in Coins – Past, Present and Future"*](https://web.archive.org/web/20060929095200/http:/www.nidi.org/index.cfm/ci_id/160.htm)*. The Nickel Institute. Archived from* [*the original*](http://www.nidi.org/index.cfm/ci_id/160.htm) *on September 29, 2006. Retrieved November 19, 2008.*

  *Lacey, Anna (June 22, 2013).* [*"A bad penny? New coins and nickel allergy"*](https://www.bbc.co.uk/news/health-22956874)*. BBC Health Check. Retrieved July 25, 2013.*

  [*"nikkelen dubbele wapenstuiver Utrecht"*](http://www.nederlandsemunten.nl/Virtuele_munten_verzameling/Provinciaal/Provincie_Utrecht_1581-1795/Verzameling_nikkelen_dubbele_wapenstuiver_Utrecht-Birmingham_1786.htm)*. nederlandsemunten.nl.*

  *Kelly, T. D.; Matos, G. R.* [*"Nickel Statistics"*](http://minerals.usgs.gov/minerals/pubs/historical-statistics/ds140-nicke.pdf) *(PDF). U.S. Geological Survey. Retrieved 2014-08-11.*

  [*"The Life of Ni"*](https://nickelinstitute.org/~/media/Files/MediaCenter/LifeOfNi/TheLifeofNi.ashx?la=en)*. Nickel Institute.*

  [*"Nickel"*](http://minerals.usgs.gov/minerals/pubs/commodity/nickel/mcs-2013-nicke.pdf) *(PDF). U.S. Geological Survey, Mineral Commodity Summaries. January 2013.*

  [*"The Nickel Mountain Project"*](https://web.archive.org/web/20120212005749/http:/www.oregongeology.com/sub/publications/OG/OBv15n10.pdf) *(PDF). Ore Bin.* ***15*** *(10): 59–66. 1953. Archived from* [*the original*](http://www.oregongeology.com/sub/publications/OG/OBv15n10.pdf) *(PDF) on February 12, 2012. Retrieved May 7, 2015.*

  [*"Environment Writer: Nickel"*](https://web.archive.org/web/20060828211637/http:/www.environmentwriter.org/resources/backissues/chemicals/nickel.htm)*. National Safety Council. 2006. Archived from* [*the original*](http://www.environmentwriter.org/resources/backissues/chemicals/nickel.htm) *on 2006-08-28. Retrieved January 10, 2009.*

  [*"Operations & Development"*](https://web.archive.org/web/20151118181320/http:/www.lundinmining.com/s/QOU.asp?ReportID=718088)*. Lundin Mining Corporation. Archived from* [*the original*](http://www.lundinmining.com/s/QOU.asp?ReportID=718088) *on November 18, 2015. Retrieved August 10, 2014.*

  [*"Mineral Commodity Survey 2017"*](https://minerals.usgs.gov/minerals/pubs/mcs/2017/mcs2017.pdf) *(PDF). U.S. Geological Survey, Mineral Commodity Summaries 2017. January 2017.*

  [*"Mineral Commodity Survey 2016"*](https://minerals.usgs.gov/minerals/pubs/mcs/2016/mcs2016.pdf) *(PDF). U.S. Geological Survey, Mineral Commodity Summaries 2016. January 2016.*

  [*"Mineral Commodity Survey 2015"*](https://minerals.usgs.gov/minerals/pubs/mcs/2015/mcs2015.pdf) *(PDF). U.S. Geological Survey, Mineral Commodity Summaries 2015. January 2015.*

  [*"Mineral Commodity Survey 2014"*](https://minerals.usgs.gov/minerals/pubs/mcs/2014/mcs2014.pdf) *(PDF). U.S. Geological Survey, Mineral Commodity Summaries 2014. January 2014.*

  *Mond, L.; Langer, K.; Quincke, F. (1890). "Action of carbon monoxide on nickel". Journal of the Chemical Society.* ***57****: 749–753.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1039/CT8905700749*](https://doi.org/10.1039%2FCT8905700749)*.*

  *Kerfoot, Derek G. E., "Nickel",* [*Ullmann's Encyclopedia of Industrial Chemistry*](https://en.wikipedia.org/wiki/Ullmann%27s_Encyclopedia_of_Industrial_Chemistry)*, Weinheim: Wiley-VCH,* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1002/14356007.a17\_157*](https://doi.org/10.1002%2F14356007.a17_157)

  *Neikov, Oleg D.; Naboychenko, Stanislav; Gopienko, Victor G & Frishberg, Irina V (January 15, 2009).* [*Handbook of Non-Ferrous Metal Powders: Technologies and Applications*](https://books.google.com/books?id=6aP3te2hGuQC&pg=PA371)*. Elsevier. pp. 371–.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-1-85617-422-0*](https://en.wikipedia.org/wiki/Special:BookSources/978-1-85617-422-0)*. Retrieved January 9, 2012.*

  [*"LME nickel price graphs"*](https://web.archive.org/web/20090228180212/http:/www.lme.com/nickel_graphs.asp)*. London Metal Exchange. Archived from* [*the original*](http://www.lme.com/nickel_graphs.asp) *on February 28, 2009. Retrieved June 6, 2009.*

  [*"London Metal Exchange"*](https://www.lme.com/metals/non-ferrous/nickel#tabIndex=0)*. LME.com.*

  [United States Mint Moves to Limit Exportation & Melting of Coins](http://www.usmint.gov/pressroom/index.cfm?action=press_release&ID=724), The United States Mint, press release, December 14, 2006

  [*"United States Circulating Coinage Intrinsic Value Table"*](http://www.coinflation.com/)*. Coininflation.com. Retrieved September 13, 2013.*

  *Engineer, Engineering Record, Building Record, and Sanitary (1896-01-01).* [*American Plumbing Practice: From the Engineering Record (Prior to 1887 the Sanitary Engineer.) A Selected Reprint of Articles Describing Notable Plumbing Installations in the United States, and Questions and Answers on Problems Arising in Plumbing and House Draining. With Five Hundred and Thirty-six Illustrations*](https://books.google.com/books?id=DL1AAQAAMAAJ)*. Engineering record. p. 119.*

  *Davis, Joseph R. (2000).* [*"Uses of Nickel"*](https://books.google.com/?id=IePhmnbmRWkC)*. ASM Specialty Handbook: Nickel, Cobalt, and Their Alloys. ASM International. pp. 7–13.* [*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)*.*

  *Kharton, Vladislav V. (2011).* [*Solid State Electrochemistry II: Electrodes, Interfaces and Ceramic Membranes*](https://books.google.com/books?id=5n5Fwf5D2EMC&pg=PT166)*. Wiley-VCH. pp. 166–.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-3-527-32638-9*](https://en.wikipedia.org/wiki/Special:BookSources/978-3-527-32638-9)*.*

  *Bidault, F.; Brett, D. J. L.; Middleton, P. H.; Brandon, N. P.* [*"A New Cathode Design for Alkaline Fuel Cells(AFCs)"*](https://web.archive.org/web/20110720233739/http:/perso.ensem.inpl-nancy.fr/Olivier.Lottin/FDFC08/Bidault.pdf) *(PDF). Imperial College London. Archived from* [*the original*](http://perso.ensem.inpl-nancy.fr/Olivier.Lottin/FDFC08/Bidault.pdf) *(PDF) on 2011-07-20.*

  [Magnetostrictive Materials Overview](https://web.archive.org/web/20130905155229/http:/aml.seas.ucla.edu/research/areas/magnetostrictive/overview.htm). [University of California, Los Angeles](https://en.wikipedia.org/wiki/University_of_California,_Los_Angeles).

  *Angara, Raghavendra (2009).* [*High Frequency High Amplitude Magnetic Field Driving System for Magnetostrictive Actuators*](https://books.google.com/books?id=J1kKJZ-RkioC&pg=PA5)*. p. 5.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*9781109187533*](https://en.wikipedia.org/wiki/Special:BookSources/9781109187533)*.*

  *Cheburaeva, R. F.; Chaporova, I. N.; Krasina, T. I. (1992). "Structure and properties of tungsten carbide hard alloys with an alloyed nickel binder". Soviet Powder Metallurgy and Metal Ceramics.* ***31*** *(5): 423–425.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1007/BF00796252*](https://doi.org/10.1007%2FBF00796252)*.*

  [*"Silicon Investigations Krytron Pulse Power Switching Tubes"*](http://www.siliconinvestigations.com/KRYT/Krytron.HTM)*.*

  *Astrid Sigel; Helmut Sigel; Roland K. O. Sigel, eds. (2008). Nickel and Its Surprising Impact in Nature. Metal Ions in Life Sciences.* ***2****. Wiley.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-470-01671-8*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-470-01671-8)*.*

  *Sydor, Andrew; Zamble, Deborah (2013). Banci, Lucia, ed. Nickel Metallomics: General Themes Guiding Nickel Homeostasis. Dordrecht: Springer. pp. 375–416.* [*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)*.*

  *Zamble, Deborah; Rowińska-Żyrek, Magdalena; Kozlowski, Henryk (2017).* [*The Biological Chemistry of Nickel*](https://books.google.com/books?id=LQifDgAAQBAJ)*. Royal Society of Chemistry.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-1-78262-498-1*](https://en.wikipedia.org/wiki/Special:BookSources/978-1-78262-498-1)*.*

  *Covacci, Antonello; Telford, John L.; Giudice, Giuseppe Del; Parsonnet, Julie; Rappuoli, Rino (1999-05-21). "Helicobacter pylori Virulence and Genetic Geography". Science.* ***284*** *(5418): 1328–1333.* [*Bibcode*](https://en.wikipedia.org/wiki/Bibcode)*:*[*1999Sci...284.1328C*](http://adsabs.harvard.edu/abs/1999Sci...284.1328C)*.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1126/science.284.5418.1328*](https://doi.org/10.1126%2Fscience.284.5418.1328)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*10334982*](https://www.ncbi.nlm.nih.gov/pubmed/10334982)*.*

  *Cox, Gary M.; Mukherjee, Jean; Cole, Garry T.; Casadevall, Arturo; Perfect, John R. (2000-02-01).* [*"Urease as a Virulence Factor in Experimental Cryptococcosis"*](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC97161)*. Infection and Immunity.* ***68*** *(2): 443–448.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1128/IAI.68.2.443-448.2000*](https://doi.org/10.1128%2FIAI.68.2.443-448.2000)*.* [*PMC*](https://en.wikipedia.org/wiki/PubMed_Central)[*97161*](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC97161)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*10639402*](https://www.ncbi.nlm.nih.gov/pubmed/10639402)*.*

  *Stephen W., Ragdale (2014). "Chapter 6. Biochemistry of Methyl-Coenzyme M Reductase: The Nickel Metalloenzyme that Catalyzes the Final Step in Synthesis and the First Step in Anaerobic Oxidation of the Greenhouse Gas Methane". In Peter M.H. Kroneck; Martha E. Sosa Torres. The Metal-Driven Biogeochemistry of Gaseous Compounds in the Environment. Metal Ions in Life Sciences.* ***14****. Springer. pp. 125–145.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1007/978-94-017-9269-1\_6*](https://doi.org/10.1007%2F978-94-017-9269-1_6)*.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-94-017-9268-4*](https://en.wikipedia.org/wiki/Special:BookSources/978-94-017-9268-4)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*25416393*](https://www.ncbi.nlm.nih.gov/pubmed/25416393)*.*

  *Wang, Vincent C.-C.; Ragsdale, Stephen W.; Armstrong, Fraser A. (2014). "Chapter 4. Investigations of the Efficient Electrocatalytic Interconversions of Carbon Dioxide and Carbon Monoxide by Nickel-Containing Carbon Monoxide Dehydrogenases". In Peter M.H. Kroneck; Martha E. Sosa Torres. The Metal-Driven Biogeochemistry of Gaseous Compounds in the Environment. Metal Ions in Life Sciences.* ***14****. Springer. pp. 71–97.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1007/978-94-017-9269-1\_4*](https://doi.org/10.1007%2F978-94-017-9269-1_4)*.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-94-017-9268-4*](https://en.wikipedia.org/wiki/Special:BookSources/978-94-017-9268-4)*.* [*PMC*](https://en.wikipedia.org/wiki/PubMed_Central)[*4261625*](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4261625)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*25416391*](https://www.ncbi.nlm.nih.gov/pubmed/25416391)*.*

  *Szilagyi, R. K.; Bryngelson, P. A.; Maroney, M. J.; Hedman, B.; et al. (2004). "S K-Edge X-ray Absorption Spectroscopic Investigation of the Ni-Containing Superoxide Dismutase Active Site: New Structural Insight into the Mechanism". Journal of the American Chemical Society.* ***126*** *(10): 3018–3019.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1021/ja039106v*](https://doi.org/10.1021%2Fja039106v)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*15012109*](https://www.ncbi.nlm.nih.gov/pubmed/15012109)*.*

  *Greig N; Wyllie S; Vickers TJ; Fairlamb AH (2006).* [*"Trypanothione-dependent glyoxalase I in Trypanosoma cruzi"*](http://www.biochemj.org/bj/400/0217/bj4000217.htm)*. Biochemical Journal.* ***400*** *(2): 217–23.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1042/BJ20060882*](https://doi.org/10.1042%2FBJ20060882)*.* [*PMC*](https://en.wikipedia.org/wiki/PubMed_Central)[*1652828*](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1652828)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*16958620*](https://www.ncbi.nlm.nih.gov/pubmed/16958620)*.*

  *Aronsson A-C; Marmstål E; Mannervik B (1978). "Glyoxalase I, a zinc metalloenzyme of mammals and yeast". Biochemical and Biophysical Research Communications.* ***81*** *(4): 1235–1240.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1016/0006-291X(78)91268-8*](https://doi.org/10.1016%2F0006-291X%2878%2991268-8)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*352355*](https://www.ncbi.nlm.nih.gov/pubmed/352355)*.*

  *Ridderström M; Mannervik B (1996).* [*"Optimized heterologous expression of the human zinc enzyme glyoxalase I"*](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1217073)*. Biochemical Journal.* ***314*** *(Pt 2): 463–467.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1042/bj3140463*](https://doi.org/10.1042%2Fbj3140463)*.* [*PMC*](https://en.wikipedia.org/wiki/PubMed_Central)[*1217073*](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1217073)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*8670058*](https://www.ncbi.nlm.nih.gov/pubmed/8670058)*.*

  *Saint-Jean AP; Phillips KR; Creighton DJ; Stone MJ (1998). "Active monomeric and dimeric forms of Pseudomonas putida glyoxalase I: evidence for 3D domain swapping". Biochemistry.* ***37*** *(29): 10345–10353.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1021/bi980868q*](https://doi.org/10.1021%2Fbi980868q)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*9671502*](https://www.ncbi.nlm.nih.gov/pubmed/9671502)*.*

  *Thornalley, P. J. (2003). "*[*Glyoxalase I—structure, function and a critical role in the enzymatic defence against glycation*](https://en.wikipedia.org/wiki/Glycation)*". Biochemical Society Transactions.* ***31*** *(Pt 6): 1343–1348.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1042/BST0311343*](https://doi.org/10.1042%2FBST0311343)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*14641060*](https://www.ncbi.nlm.nih.gov/pubmed/14641060)*.*

  *Vander Jagt DL (1989). "Unknown chapter title". In D Dolphin; R Poulson; O Avramovic. Coenzymes and Cofactors VIII: Glutathione Part A. New York: John Wiley and Sons.*

  *Zambelli, Barbara; Ciurli, Stefano (2013). "Chapter 10. Nickel: and Human Health". 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. 321–357.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1007/978-94-007-7500-8\_10*](https://doi.org/10.1007%2F978-94-007-7500-8_10)*.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-94-007-7499-5*](https://en.wikipedia.org/wiki/Special:BookSources/978-94-007-7499-5)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*24470096*](https://www.ncbi.nlm.nih.gov/pubmed/24470096)*.*

  Nickel. IN: [Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Copper](https://www.nap.edu/read/10026/chapter/15). National Academy Press. 2001, PP. 521–529.

  *Kamerud KL; Hobbie KA; Anderson KA (August 28, 2013).* [*"Stainless Steel Leaches Nickel and Chromium into Foods During Cooking"*](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4284091)*. Journal of Agricultural and Food Chemistry.* ***61*** *(39): 9495–501.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1021/jf402400v*](https://doi.org/10.1021%2Fjf402400v)*.* [*PMC*](https://en.wikipedia.org/wiki/PubMed_Central)[*4284091*](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4284091)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*23984718*](https://www.ncbi.nlm.nih.gov/pubmed/23984718)*.*

  *Flint GN; Packirisamy S (Feb–Mar 1997). "Purity of food cooked in stainless steel utensils". Food Additives & Contaminants.* ***14*** *(2): 115–26.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1080/02652039709374506*](https://doi.org/10.1080%2F02652039709374506)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*9102344*](https://www.ncbi.nlm.nih.gov/pubmed/9102344)*.*

  *Schirber, Michael (July 27, 2014).* [*"Microbe's Innovation May Have Started Largest Extinction Event on Earth"*](http://www.space.com/26654-microbe-innovation-started-largest-earth-extinction.html)*. Space.com. Astrobiology Magazine. .... That spike in nickel allowed methanogens to take off.*

  [*"Nickel 357553"*](https://www.sigmaaldrich.com/catalog/product/aldrich/357553?lang=en&region=US)*.*

  *Haber, Lynne T; Bates, Hudson K; Allen, Bruce C; Vincent, Melissa J; Oller, Adriana R (2017). "Derivation of an oral toxicity reference value for nickel".* [*Regulatory Toxicology and Pharmacology*](https://en.wikipedia.org/wiki/Regulatory_Toxicology_and_Pharmacology)*.* ***87****: S1–S18.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1016/j.yrtph.2017.03.011*](https://doi.org/10.1016%2Fj.yrtph.2017.03.011)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*28300623*](https://www.ncbi.nlm.nih.gov/pubmed/28300623)*.*

  *Butticè, Claudio (2015). "Nickel Compounds". In Colditz, Graham A. The SAGE Encyclopedia of Cancer and Society (Second ed.). Thousand Oaks: SAGE Publications, Inc. pp. 828–831.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*9781483345734*](https://en.wikipedia.org/wiki/Special:BookSources/9781483345734)*.*

  IARC (2012). [“Nickel and nickel compounds”](https://monographs.iarc.fr/ENG/Monographs/vol100C/mono100C-10.pdf) in *IARC Monogr Eval Carcinog Risks Hum*. Volume 100C. pp. 169–218..

  Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on Classification, Labelling and Packaging of Substances and Mixtures, Amending and Repealing Directives 67/548/EEC and 1999/45/EC and amending Regulation (EC) No 1907/2006 [OJ L 353, 31.12.2008, p. 1]. [Annex VI](http://www.eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32008R1272). Accessed July 13, 2017.

  [Globally Harmonised System of Classification and Labelling of Chemicals (GHS)](https://www.unece.org/fileadmin/DAM/trans/danger/publi/ghs/ghs_rev05/English/ST-SG-AC10-30-REv5e.pdf), 5th ed., United Nations, New York and Geneva, 2013..

  National Toxicology Program. (2016). [“Report on Carcinogens”](https://ntp.niehs.nih.gov/pubhealth/roc/index-1.html), 14th ed. Research Triangle Park, NC: U.S. Department of Health and Human Services, Public Health Service..

  *"Report of the International Committee on Nickel Carcinogenesis in Man". Scandinavian Journal of Work, Environment & Health.* ***16*** *(1 Spec No): 1–82. 1990.* [*JSTOR*](https://en.wikipedia.org/wiki/JSTOR)[*40965957*](https://www.jstor.org/stable/40965957)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*2185539*](https://www.ncbi.nlm.nih.gov/pubmed/2185539)*.*

  *"NTP Toxicology and Carcinogenesis Studies of Nickel Subsulfide (CAS No. 12035-72-2) in F344 Rats and B6C3F1 Mice (Inhalation Studies)". National Toxicology Program Technical Report Series.* ***453****: 1–365. 1996.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*12594522*](https://www.ncbi.nlm.nih.gov/pubmed/12594522)*.*

  *"NTP Toxicology and Carcinogenesis Studies of Nickel Oxide (CAS No. 1313-99-1) in F344 Rats and B6C3F1 Mice (Inhalation Studies)". National Toxicology Program Technical Report Series.* ***451****: 1–381. 1996.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*12594524*](https://www.ncbi.nlm.nih.gov/pubmed/12594524)*.*

  *Cogliano, V. J; Baan, R; Straif, K; Grosse, Y; Lauby-Secretan, B; El Ghissassi, F; Bouvard, V; Benbrahim-Tallaa, L; Guha, N; Freeman, C; Galichet, L; Wild, C. P (2011).* [*"Preventable exposures associated with human cancers"*](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3243677)*. JNCI Journal of the National Cancer Institute.* ***103*** *(24): 1827–39.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1093/jnci/djr483*](https://doi.org/10.1093%2Fjnci%2Fdjr483)*.* [*PMC*](https://en.wikipedia.org/wiki/PubMed_Central)[*3243677*](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3243677)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*22158127*](https://www.ncbi.nlm.nih.gov/pubmed/22158127)*.*

  *Heim, K. E; Bates, H. K; Rush, R. E; Oller, A. R (2007). "Oral carcinogenicity study with nickel sulfate hexahydrate in Fischer 344 rats". Toxicology and Applied Pharmacology.* ***224*** *(2): 126–37.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1016/j.taap.2007.06.024*](https://doi.org/10.1016%2Fj.taap.2007.06.024)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*17692353*](https://www.ncbi.nlm.nih.gov/pubmed/17692353)*.*

  *Oller, A. R; Kirkpatrick, D. T; Radovsky, A; Bates, H. K (2008). "Inhalation carcinogenicity study with nickel metal powder in Wistar rats". Toxicology and Applied Pharmacology.* ***233*** *(2): 262–75.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1016/j.taap.2008.08.017*](https://doi.org/10.1016%2Fj.taap.2008.08.017)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*18822311*](https://www.ncbi.nlm.nih.gov/pubmed/18822311)*.*

  *"NTP Toxicology and Carcinogenesis Studies of Nickel Sulfate Hexahydrate (CAS No. 10101-97-0) in F344 Rats and B6C3F1 Mice (Inhalation Studies)". National Toxicology Program Technical Report Series.* ***454****: 1–380. 1996.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*12587012*](https://www.ncbi.nlm.nih.gov/pubmed/12587012)*.*

  Springborn Laboratories Inc. (2000). “An Oral (Gavage) Two-generation Reproduction Toxicity Study in Sprague-Dawley Rats with Nickel Sulfate Hexahydrate.” Final Report. Springborn Laboratories Inc., Spencerville. SLI Study No. 3472.4.

  *Vaktskjold, A; Talykova, L. V; Chashchin, V. P; Nieboer, E; Thomassen, Y; Odland, J. O (2006). "Genital malformations in newborns of female nickel-refinery workers". Scandinavian Journal of Work, Environment & Health.* ***32*** *(1): 41–50.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.5271/sjweh.975*](https://doi.org/10.5271%2Fsjweh.975)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*16539171*](https://www.ncbi.nlm.nih.gov/pubmed/16539171)*.*

  *Vaktskjold, A; Talykova, L. V; Chashchin, V. P; Odland, Jon Ø; Nieboer, E (2008). "Spontaneous abortions among nickel-exposed female refinery workers". International Journal of Environmental Health Research.* ***18*** *(2): 99–115.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1080/09603120701498295*](https://doi.org/10.1080%2F09603120701498295)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*18365800*](https://www.ncbi.nlm.nih.gov/pubmed/18365800)*.*

  *Vaktskjold, A; Talykova, L. V; Chashchin, V. P; Odland, J. O; Nieboer, E (2007). "Small-for-gestational-age newborns of female refinery workers exposed to nickel". International Journal of Occupational Medicine and Environmental Health.* ***20*** *(4): 327–38.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.2478/v10001-007-0034-0*](https://doi.org/10.2478%2Fv10001-007-0034-0)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*18165195*](https://www.ncbi.nlm.nih.gov/pubmed/18165195)*.*

  *Vaktskjold, A; Talykova, L. V; Chashchin, V. P; Odland, J. O; Nieboer, E (2008). "Maternal nickel exposure and congenital musculoskeletal defects". American Journal of Industrial Medicine.* ***51*** *(11): 825–33.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1002/ajim.20609*](https://doi.org/10.1002%2Fajim.20609)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*18655106*](https://www.ncbi.nlm.nih.gov/pubmed/18655106)*.*

  [*"CDC – NIOSH Pocket Guide to Chemical Hazards – Nickel metal and other compounds (as Ni)"*](https://www.cdc.gov/niosh/npg/npgd0445.html)*. www.cdc.gov. Retrieved 2015-11-20.*

  *Stellman, Jeanne Mager (1998).* [*Encyclopaedia of Occupational Health and Safety: Chemical, industries and occupations*](https://books.google.com/books?id=nDhpLa1rl44C&pg=PT133)*. International Labour Organization. pp. 133–.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-92-2-109816-4*](https://en.wikipedia.org/wiki/Special:BookSources/978-92-2-109816-4)*. Retrieved January 9, 2012.*

  *Barceloux, Donald G.; Barceloux, Donald (1999). "Nickel". Clinical Toxicology.* ***37*** *(2): 239–258.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1081/CLT-100102423*](https://doi.org/10.1081%2FCLT-100102423)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*10382559*](https://www.ncbi.nlm.nih.gov/pubmed/10382559)*.*

  [Position Statement on Nickel Sensitivity](https://www.aad.org/Forms/Policies/Uploads/PS/PS-Nickel%20Sensitivity.pdf). American Academy of Dermatology(August 22, 2015)

  *Thyssen J. P.; Linneberg A.; Menné T.; Johansen J. D. (2007). "The epidemiology of contact allergy in the general population—prevalence and main findings". Contact Dermatitis.* ***57*** *(5): 287–99.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1111/j.1600-0536.2007.01220.x*](https://doi.org/10.1111%2Fj.1600-0536.2007.01220.x)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*17937743*](https://www.ncbi.nlm.nih.gov/pubmed/17937743)*.*

  [Dermal Exposure: Nickel Alloys](http://www.nipera.org/WorkplaceGuide/ToxicityOfNickelCompounds/NickelAlloys/DermalExposureNickel%20Alloys.aspx) Nickel Producers Environmental Research Association (NiPERA), accessed 2016 Feb.11

  *Nestle, O.; Speidel, H.; Speidel, M. O. (2002). "High nickel release from 1- and 2-euro coins". Nature.* ***419*** *(6903): 132.* [*Bibcode*](https://en.wikipedia.org/wiki/Bibcode)*:*[*2002Natur.419..132N*](http://adsabs.harvard.edu/abs/2002Natur.419..132N)*.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1038/419132a*](https://doi.org/10.1038%2F419132a)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*12226655*](https://www.ncbi.nlm.nih.gov/pubmed/12226655)*.*

  *Dow, Lea (June 3, 2008).* [*"Nickel Named 2008 Contact Allergen of the Year"*](https://web.archive.org/web/20090203033929/http:/www.nickelallergyinformation.com/2008/06/nickel-named-2008-contact-alle.htm)*. Nickel Allergy Information. Archived from* [*the original*](http://www.nickelallergyinformation.com/2008/06/nickel-named-2008-contact-alle.htm) *on 2009-02-03.*

  *Salnikow, k.; Donald, S. P.; Bruick, R. K.; Zhitkovich, A.; et al. (September 2004). "Depletion of intracellular ascorbate by the carcinogenic metal nickel and cobalt results in the induction of hypoxic stress". Journal of Biological Chemistry.* ***279*** *(39): 40337–44.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1074/jbc.M403057200*](https://doi.org/10.1074%2Fjbc.M403057200)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*15271983*](https://www.ncbi.nlm.nih.gov/pubmed/15271983)*.*

* 1.  *Das, K. K.; Das, S. N.; Dhundasi, S. A. (2008).* [*"Nickel, its adverse health effects and oxidative stress"*](http://www.icmr.nic.in/ijmr/2008/october/1005.pdf) *(PDF). Indian Journal of Medical Research.* ***128*** *(4): 117–131.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*19106437*](https://www.ncbi.nlm.nih.gov/pubmed/19106437)*. Retrieved August 22, 2011.*

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* [CDC – Nickel – NIOSH Workplace Safety and Health Topic](https://www.cdc.gov/niosh/topics/nickel/)
* [An occupational hygiene assessment of dermal nickel exposures in primary production industries](http://www.iom-world.org/pubs/IOM_TM0405.pdf) by GW Hughson. [Institute of Occupational Medicine](https://en.wikipedia.org/wiki/Institute_of_Occupational_Medicine) Research Report TM/04/05
* [An occupational hygiene assessment of dermal nickel exposures in primary production and primary user industries. Phase 2 Report](http://www.iom-world.org/pubs/IOM_TM0506.pdf) by GW Hughson. [Institute of Occupational Medicine](https://en.wikipedia.org/wiki/Institute_of_Occupational_Medicine) Research Report TM/05/06
* ["The metal that brought you cheap flights"](https://www.bbc.com/news/magazine-32749262), *BBC*

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| * [**v**](https://en.wikipedia.org/wiki/Template:Periodic_table_(32_columns,_compact)) * [**t**](https://en.wikipedia.org/wiki/Template_talk:Periodic_table_(32_columns,_compact)) * [**e**](https://en.wikipedia.org/w/index.php?title=Template:Periodic_table_(32_columns,_compact)&action=edit)   [**Periodic table**](https://en.wikipedia.org/wiki/Periodic_table)[**(Large cells)**](https://en.wikipedia.org/wiki/Periodic_table_(large_cells)) | |
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