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**Germanium**

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Not to be confused with [geranium](https://en.wikipedia.org/wiki/Geranium).

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| --- | --- |
| Germanium,  32Ge | |
| [Grayish lustrous block with uneven cleaved surface](https://en.wikipedia.org/wiki/File:Polycrystalline-germanium.jpg) | |
| **General properties** | |
| **Pronunciation** | [/dʒərˈmeɪniəm/](https://en.wikipedia.org/wiki/Help:IPA/English) ​([*jər-MAY-nee-əm*](https://en.wikipedia.org/wiki/Help:Pronunciation_respelling_key)) |
| **Appearance** | grayish-white |
| [**Standard atomic weight**](https://en.wikipedia.org/wiki/Standard_atomic_weight) **(*A*r, standard)** | 72.630(8)[[1]](https://en.wikipedia.org/wiki/Germanium#cite_note-CIAAW2016-1) |
| **Germanium in the** [**periodic table**](https://en.wikipedia.org/wiki/Periodic_table) | |
| |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 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[Neon](https://en.wikipedia.org/wiki/Neon) | | [Sodium](https://en.wikipedia.org/wiki/Sodium) | [Magnesium](https://en.wikipedia.org/wiki/Magnesium) |  | | | | | | | | | | | | | | | | | | | | | | | | [Aluminium](https://en.wikipedia.org/wiki/Aluminium) | [Silicon](https://en.wikipedia.org/wiki/Silicon) | [Phosphorus](https://en.wikipedia.org/wiki/Phosphorus) | [Sulfur](https://en.wikipedia.org/wiki/Sulfur) | [Chlorine](https://en.wikipedia.org/wiki/Chlorine) | [Argon](https://en.wikipedia.org/wiki/Argon) | | [Potassium](https://en.wikipedia.org/wiki/Potassium) | [Calcium](https://en.wikipedia.org/wiki/Calcium) | [Scandium](https://en.wikipedia.org/wiki/Scandium) |  | | | | | | | | | | | | | | [Titanium](https://en.wikipedia.org/wiki/Titanium) | [Vanadium](https://en.wikipedia.org/wiki/Vanadium) | [Chromium](https://en.wikipedia.org/wiki/Chromium) | [Manganese](https://en.wikipedia.org/wiki/Manganese) | [Iron](https://en.wikipedia.org/wiki/Iron) | [Cobalt](https://en.wikipedia.org/wiki/Cobalt) | [Nickel](https://en.wikipedia.org/wiki/Nickel) | [Copper](https://en.wikipedia.org/wiki/Copper) | [Zinc](https://en.wikipedia.org/wiki/Zinc) | [Gallium](https://en.wikipedia.org/wiki/Gallium) | Germanium | [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) | | [Si](https://en.wikipedia.org/wiki/Silicon) ↑ **Ge** ↓ [Sn](https://en.wikipedia.org/wiki/Tin) | | [gallium](https://en.wikipedia.org/wiki/Gallium) ← **germanium** → [arsenic](https://en.wikipedia.org/wiki/Arsenic) | | | | |
| [**Atomic number**](https://en.wikipedia.org/wiki/Atomic_number)(*Z*) | 32 |
| [**Group**](https://en.wikipedia.org/wiki/Group_(periodic_table)) | [group 14 (carbon group)](https://en.wikipedia.org/wiki/Carbon_group) |
| [**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)) | [p-block](https://en.wikipedia.org/wiki/P-block) |
| [**Element category**](https://en.wikipedia.org/wiki/Names_for_sets_of_chemical_elements#Category) | [metalloid](https://en.wikipedia.org/wiki/Metalloid) |
| [**Electron configuration**](https://en.wikipedia.org/wiki/Electron_configuration) | [[Ar](https://en.wikipedia.org/wiki/Argon)] 3d10 4s2 4p2 |
| Electrons per shell | 2, 8, 18, 4 |
| **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) | 1211.40 [K](https://en.wikipedia.org/wiki/Kelvin) ​(938.25 °C, ​1720.85 °F) |
| [**Boiling point**](https://en.wikipedia.org/wiki/Boiling_point) | 3106 K ​(2833 °C, ​5131 °F) |
| [**Density**](https://en.wikipedia.org/wiki/Density)(near r.t.) | 5.323 g/cm3 |
| when liquid (at m.p.) | 5.60 g/cm3 |
| [**Heat of fusion**](https://en.wikipedia.org/wiki/Enthalpy_of_fusion) | 36.94 [kJ/mol](https://en.wikipedia.org/wiki/Kilojoule_per_mole) |
| [**Heat of vaporization**](https://en.wikipedia.org/wiki/Enthalpy_of_vaporization) | 334 kJ/mol |
| [**Molar heat capacity**](https://en.wikipedia.org/wiki/Molar_heat_capacity) | 23.222 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) | 1644 | 1814 | 2023 | 2287 | 2633 | 3104 | | |
| **Atomic properties** | |
| [**Oxidation states**](https://en.wikipedia.org/wiki/Oxidation_state) | **−4** −3, −2, −1, 0, +1, **+2**, +3, **+4** (an [amphoteric](https://en.wikipedia.org/wiki/Amphoterism) oxide) |
| [**Electronegativity**](https://en.wikipedia.org/wiki/Electronegativity) | Pauling scale: 2.01 |
| [**Ionization energies**](https://en.wikipedia.org/wiki/Ionization_energy) | * 1st: 762 kJ/mol * 2nd: 1537.5 kJ/mol * 3rd: 3302.1 kJ/mol |
| [**Atomic radius**](https://en.wikipedia.org/wiki/Atomic_radius) | empirical: 122 [pm](https://en.wikipedia.org/wiki/Picometre) |
| [**Covalent radius**](https://en.wikipedia.org/wiki/Covalent_radius) | 122 pm |
| [**Van der Waals radius**](https://en.wikipedia.org/wiki/Van_der_Waals_radius) | 211 pm |
| [Color lines in a spectral range](https://en.wikipedia.org/wiki/File:Germanium_spectrum_visible.png)  [**Spectral lines**](https://en.wikipedia.org/wiki/Spectral_line) **of germanium** | |
| **Other properties** | |
| [**Crystal structure**](https://en.wikipedia.org/wiki/Crystal_structure) | ​[face-centered diamond-cubic](https://en.wikipedia.org/wiki/Diamond_cubic)  [Diamond cubic crystal structure for germanium](https://en.wikipedia.org/wiki/File:Diamond_cubic_crystal_structure.svg) |
| [**Speed of sound**](https://en.wikipedia.org/wiki/Speed_of_sound)thin rod | 5400 m/s (at 20 °C) |
| [**Thermal expansion**](https://en.wikipedia.org/wiki/Coefficient_of_thermal_expansion) | 6.0 µm/(m·K) |
| [**Thermal conductivity**](https://en.wikipedia.org/wiki/Thermal_conductivity) | 60.2 W/(m·K) |
| [**Electrical resistivity**](https://en.wikipedia.org/wiki/Electrical_resistivity_and_conductivity) | 1 Ω·m (at 20 °C) |
| [**Band gap**](https://en.wikipedia.org/wiki/Band_gap) | 0.67 [eV](https://en.wikipedia.org/wiki/Electronvolt) (at 300 K) |
| [**Magnetic ordering**](https://en.wikipedia.org/wiki/Magnetism) | [diamagnetic](https://en.wikipedia.org/wiki/Diamagnetic)[[2]](https://en.wikipedia.org/wiki/Germanium#cite_note-2) |
| [**Magnetic susceptibility**](https://en.wikipedia.org/wiki/Magnetic_susceptibility) | −76.84·10−6 cm3/mol[[3]](https://en.wikipedia.org/wiki/Germanium#cite_note-3) |
| [**Young's modulus**](https://en.wikipedia.org/wiki/Young%27s_modulus) | 103 GPa[[4]](https://en.wikipedia.org/wiki/Germanium#cite_note-ioffe-4) |
| [**Shear modulus**](https://en.wikipedia.org/wiki/Shear_modulus) | 41 GPa[[4]](https://en.wikipedia.org/wiki/Germanium#cite_note-ioffe-4) |
| [**Bulk modulus**](https://en.wikipedia.org/wiki/Bulk_modulus) | 75 GPa[[4]](https://en.wikipedia.org/wiki/Germanium#cite_note-ioffe-4) |
| [**Poisson ratio**](https://en.wikipedia.org/wiki/Poisson%27s_ratio) | 0.26[[4]](https://en.wikipedia.org/wiki/Germanium#cite_note-ioffe-4) |
| [**Mohs hardness**](https://en.wikipedia.org/wiki/Mohs_scale_of_mineral_hardness) | 6.0 |
| [**CAS Number**](https://en.wikipedia.org/wiki/CAS_Registry_Number) | 7440-56-4 |
| **History** | |
| **Naming** | after [Germany](https://en.wikipedia.org/wiki/Germany), homeland of the discoverer |
| **Prediction** | [Dmitri Mendeleev](https://en.wikipedia.org/wiki/Dmitri_Mendeleev) (1871) |
| [**Discovery**](https://en.wikipedia.org/wiki/Timeline_of_chemical_element_discoveries) | [Clemens Winkler](https://en.wikipedia.org/wiki/Clemens_Winkler) (1886) |
| **Main** [**isotopes of germanium**](https://en.wikipedia.org/wiki/Isotopes_of_germanium) | |
| |  |  |  |  |  | | --- | --- | --- | --- | --- | | [**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) | | **68Ge** | [syn](https://en.wikipedia.org/wiki/Synthetic_radioisotope) | 270.8 d | [ε](https://en.wikipedia.org/wiki/Electron_capture) | [68Ga](https://en.wikipedia.org/wiki/Gallium-68) | | **70Ge** | 20.52% | [stable](https://en.wikipedia.org/wiki/Stable_isotope) | | | | **71Ge** | syn | 11.3 d | ε | [71Ga](https://en.wikipedia.org/wiki/Gallium-71) | | **72Ge** | 27.45% | stable | | | | **73Ge** | 7.76% | stable | | | | **74Ge** | 36.52% | stable | | | | **76Ge** | 7.75% | 1.78×1021 y | [β−β−](https://en.wikipedia.org/wiki/Double_beta_decay) | [76Se](https://en.wikipedia.org/wiki/Selenium-76) | | |
| * [view](https://en.wikipedia.org/wiki/Template:Infobox_germanium) * [talk](https://en.wikipedia.org/wiki/Template_talk:Infobox_germanium) * [edit](https://en.wikipedia.org/w/index.php?title=Template:Infobox_germanium&action=edit)   | [references](https://en.wikipedia.org/wiki/List_of_data_references_for_chemical_elements) | |

**Germanium** is a [chemical element](https://en.wikipedia.org/wiki/Chemical_element) with symbol Ge and [atomic number](https://en.wikipedia.org/wiki/Atomic_number) 32. It is a lustrous, hard, grayish-white [metalloid](https://en.wikipedia.org/wiki/Metalloid) in the [carbon group](https://en.wikipedia.org/wiki/Carbon_group), chemically similar to its group neighbors [tin](https://en.wikipedia.org/wiki/Tin) and [silicon](https://en.wikipedia.org/wiki/Silicon). Pure germanium is a [semiconductor](https://en.wikipedia.org/wiki/Semiconductor) with an appearance similar to elemental silicon. Like silicon, germanium naturally reacts and forms complexes with [oxygen](https://en.wikipedia.org/wiki/Oxygen) in nature.

Because it seldom appears in high concentration, germanium was discovered comparatively late in the history of chemistry. Germanium ranks near fiftieth [in relative abundance of the elements in the Earth's crust](https://en.wikipedia.org/wiki/Abundance_of_elements_in_Earth%27s_crust). In 1869, [Dmitri Mendeleev](https://en.wikipedia.org/wiki/Dmitri_Mendeleev) [predicted](https://en.wikipedia.org/wiki/Mendeleev%27s_predicted_elements) its existence and some of its properties from its position on his [periodic table](https://en.wikipedia.org/wiki/Periodic_table), and called the element [**ekasilicon**](https://en.wikipedia.org/wiki/Mendeleev%27s_predicted_elements#Ekasilicon_and_germanium). Nearly two decades later, in 1886, [Clemens Winkler](https://en.wikipedia.org/wiki/Clemens_Winkler) found the new element along with [silver](https://en.wikipedia.org/wiki/Silver) and [sulfur](https://en.wikipedia.org/wiki/Sulfur), in a rare mineral called [argyrodite](https://en.wikipedia.org/wiki/Argyrodite). Although the new element somewhat resembled [arsenic](https://en.wikipedia.org/wiki/Arsenic) and [antimony](https://en.wikipedia.org/wiki/Antimony) in appearance, the combining ratios in compounds agreed with Mendeleev's predictions for a relative of silicon. Winkler named the element after his country, [Germany](https://en.wikipedia.org/wiki/German_Empire). Today, germanium is mined primarily from [sphalerite](https://en.wikipedia.org/wiki/Sphalerite) (the primary ore of zinc), though germanium is also recovered commercially from [silver](https://en.wikipedia.org/wiki/Silver), [lead](https://en.wikipedia.org/wiki/Lead), and [copper](https://en.wikipedia.org/wiki/Copper) [ores](https://en.wikipedia.org/wiki/Ore).

Elemental germanium is used as a semiconductor in [transistors](https://en.wikipedia.org/wiki/Transistor) and various other electronic devices. Historically, the first decade of semiconductor electronics was based entirely on germanium. Today, the amount of germanium produced for semiconductor electronics is one fiftieth the amount of ultra-high purity silicon produced for the same. Presently, the major end uses are [fibre-optic](https://en.wikipedia.org/wiki/Fibre-optic) systems, [infrared optics](https://en.wikipedia.org/wiki/Infrared_vision), [solar cell](https://en.wikipedia.org/wiki/Solar_cell) applications, and [light-emitting diodes](https://en.wikipedia.org/wiki/Light-emitting_diode) (LEDs). Germanium compounds are also used for [polymerization](https://en.wikipedia.org/wiki/Polymerization) catalysts and have most recently found use in the production of [nanowires](https://en.wikipedia.org/wiki/Nanowire). This element forms a large number of [organometallic](https://en.wikipedia.org/wiki/Organometallic) compounds, such as [tetraethylgermane](https://en.wikipedia.org/wiki/Tetraethylgermane), useful in [organometallic chemistry](https://en.wikipedia.org/wiki/Organometallic_chemistry).

Germanium is not thought to be an essential element for any living organism. Some complex organic germanium compounds are being investigated as possible pharmaceuticals, though none have yet proven successful. Similar to silicon and aluminum, natural germanium compounds tend to be insoluble in water and thus have little oral [toxicity](https://en.wikipedia.org/wiki/Toxicity). However, synthetic soluble germanium salts are [nephrotoxic](https://en.wikipedia.org/wiki/Nephrotoxic), and synthetic chemically reactive germanium compounds with [halogens](https://en.wikipedia.org/wiki/Halogen) and [hydrogen](https://en.wikipedia.org/wiki/Hydrogen) are irritants and toxins.



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**History**

See also: [History of the transistor](https://en.wikipedia.org/wiki/History_of_the_transistor)

[](https://en.wikipedia.org/wiki/File:Winkler_preparate_1886_1904.png)

Samples of germanium compounds prepared by [Clemens Winkler](https://en.wikipedia.org/wiki/Clemens_Winkler), discoverer of the element

In his report on *The Periodic Law of the Chemical Elements* in 1869, the Russian chemist [Dmitri Mendeleev](https://en.wikipedia.org/wiki/Dmitri_Mendeleev) predicted the existence of several unknown [chemical elements](https://en.wikipedia.org/wiki/Chemical_element), including one that would fill a gap in the [carbon family](https://en.wikipedia.org/wiki/Group_14_element), located between [silicon](https://en.wikipedia.org/wiki/Silicon) and [tin](https://en.wikipedia.org/wiki/Tin).[[5]](https://en.wikipedia.org/wiki/Germanium#cite_note-5) Because of its position in his Periodic Table, Mendeleev called it *ekasilicon (Es)*, and he estimated its [atomic weight](https://en.wikipedia.org/wiki/Atomic_weight) to be about 72.0.

In mid-1885, at a mine near [Freiberg, Saxony](https://en.wikipedia.org/wiki/Freiberg,_Saxony), a new [mineral](https://en.wikipedia.org/wiki/Mineral) was discovered and named [*argyrodite*](https://en.wikipedia.org/wiki/Argyrodite) because of the high [silver](https://en.wikipedia.org/wiki/Silver) content.[[n 1]](https://en.wikipedia.org/wiki/Germanium#cite_note-7) The chemist [Clemens Winkler](https://en.wikipedia.org/wiki/Clemens_Winkler) analyzed this new mineral, which proved to be a combination of silver, sulfur, and a new element. Winkler was able to isolate the new element in 1886 and found it similar to [antimony](https://en.wikipedia.org/wiki/Antimony). He initially considered the new element to be eka-antimony, but was soon convinced that it was instead eka-silicon.[[7]](https://en.wikipedia.org/wiki/Germanium#cite_note-Winkle2-8)[[8]](https://en.wikipedia.org/wiki/Germanium#cite_note-isolation-9) Before Winkler published his results on the new element, he decided that he would name his element *neptunium*, since the recent discovery of planet [Neptune](https://en.wikipedia.org/wiki/Neptune) in 1846 had similarly been preceded by mathematical predictions of its existence.[[n 2]](https://en.wikipedia.org/wiki/Germanium#cite_note-12) However, the name "neptunium" had already been given to another proposed chemical element (though not the element that today bears the name [neptunium](https://en.wikipedia.org/wiki/Neptunium), which was discovered in 1940).[[n 3]](https://en.wikipedia.org/wiki/Germanium#cite_note-17) So instead, Winkler named the new element *germanium* (from the [Latin](https://en.wikipedia.org/wiki/Latin) word, *Germania*, for Germany) in honor of his homeland.[[8]](https://en.wikipedia.org/wiki/Germanium#cite_note-isolation-9) Argyrodite proved empirically to be Ag8GeS6.

Because this new element showed some similarities with the elements [arsenic](https://en.wikipedia.org/wiki/Arsenic) and antimony, its proper place in the periodic table was under consideration, but its similarities with Dmitri Mendeleev's predicted element "ekasilicon" confirmed that place on the periodic table.[[8]](https://en.wikipedia.org/wiki/Germanium#cite_note-isolation-9)[[15]](https://en.wikipedia.org/wiki/Germanium#cite_note-18) With further material from 500 kg of ore from the mines in Saxony, Winkler confirmed the chemical properties of the new element in 1887.[[7]](https://en.wikipedia.org/wiki/Germanium#cite_note-Winkle2-8)[[8]](https://en.wikipedia.org/wiki/Germanium#cite_note-isolation-9)[[16]](https://en.wikipedia.org/wiki/Germanium#cite_note-19) He also determined an atomic weight of 72.32 by analyzing pure [germanium tetrachloride](https://en.wikipedia.org/wiki/Germanium_tetrachloride) (GeCl  
4), while [Lecoq de Boisbaudran](https://en.wikipedia.org/wiki/Lecoq_de_Boisbaudran) deduced 72.3 by a comparison of the lines in the spark [spectrum](https://en.wikipedia.org/wiki/Spectrum) of the element.[[17]](https://en.wikipedia.org/wiki/Germanium#cite_note-20)

Winkler was able to prepare several new compounds of germanium, including [fluorides](https://en.wikipedia.org/wiki/Fluoride), [chlorides](https://en.wikipedia.org/wiki/Chloride), [sulfides](https://en.wikipedia.org/wiki/Sulfide), [dioxide](https://en.wikipedia.org/wiki/Germanium_dioxide), and [tetraethylgermane](https://en.wikipedia.org/wiki/Tetraethylgermane) (Ge(C2H5)4), the first organogermane.[[7]](https://en.wikipedia.org/wiki/Germanium#cite_note-Winkle2-8) The physical data from those compounds — which corresponded well with Mendeleev's predictions — made the discovery an important confirmation of Mendeleev's idea of element [periodicity](https://en.wikipedia.org/wiki/Periodic_table). Here is a comparison between the prediction and Winkler's data:[[7]](https://en.wikipedia.org/wiki/Germanium#cite_note-Winkle2-8)

|  |  |  |
| --- | --- | --- |
| **Property** | **Ekasilicon Mendeleev prediction (1871)** | **Germanium Winkler (1887)** |
| atomic mass | 72.64 | 72.59 |
| density (g/cm3) | 5.5 | 5.35 |
| melting point (°C) | high | 947 |
| color | gray | gray |
| oxide type | [refractory](https://en.wikipedia.org/wiki/Refractory) dioxide | refractory dioxide |
| oxide density (g/cm3) | 4.7 | 4.7 |
| oxide activity | feebly basic | feebly basic |
| chloride boiling point (°C) | under 100 | 86 (GeCl4) |
| chloride density (g/cm3) | 1.9 | 1.9 |

Until the late 1930s, germanium was thought to be a poorly conducting [metal](https://en.wikipedia.org/wiki/Metal).[[18]](https://en.wikipedia.org/wiki/Germanium#cite_note-DOE-21) Germanium did not become economically significant until after 1945 when its properties as an [electronic](https://en.wikipedia.org/wiki/Electronics) semiconductor were recognized. During [World War II](https://en.wikipedia.org/wiki/World_War_II), small amounts of germanium were used in some special [electronic devices](https://en.wikipedia.org/wiki/Electronics), mostly [diodes](https://en.wikipedia.org/wiki/Diode).[[19]](https://en.wikipedia.org/wiki/Germanium#cite_note-22)[[20]](https://en.wikipedia.org/wiki/Germanium#cite_note-23) The first major use was the point-contact [Schottky diodes](https://en.wikipedia.org/wiki/Schottky_diode) for [radar](https://en.wikipedia.org/wiki/Radar) pulse detection during the War.[[18]](https://en.wikipedia.org/wiki/Germanium#cite_note-DOE-21) The first [silicon-germanium](https://en.wikipedia.org/wiki/Silicon-germanium) alloys were obtained in 1955.[[21]](https://en.wikipedia.org/wiki/Germanium#cite_note-24) Before 1945, only a few hundred kilograms of germanium were produced in smelters each year, but by the end of the 1950s, the annual worldwide production had reached 40 [metric tons](https://en.wikipedia.org/wiki/Metric_ton).[[22]](https://en.wikipedia.org/wiki/Germanium#cite_note-acs-25)

The development of the germanium [transistor](https://en.wikipedia.org/wiki/Transistor) in 1948[[23]](https://en.wikipedia.org/wiki/Germanium#cite_note-26) opened the door to countless applications of [solid state electronics](https://en.wikipedia.org/wiki/Solid_state_(electronics)).[[24]](https://en.wikipedia.org/wiki/Germanium#cite_note-27) From 1950 through the early 1970s, this area provided an increasing market for germanium, but then high-purity silicon began replacing germanium in transistors, diodes, and [rectifiers](https://en.wikipedia.org/wiki/Rectifier).[[25]](https://en.wikipedia.org/wiki/Germanium#cite_note-usgs-28) For example, the company that became [Fairchild Semiconductor](https://en.wikipedia.org/wiki/Fairchild_Semiconductor) was founded in 1957 with the express purpose of producing silicon transistors. Silicon has superior electrical properties, but it requires much greater purity that could not be commercially achieved in the early years of [semiconductor electronics](https://en.wikipedia.org/wiki/Solid-state_electronics).[[26]](https://en.wikipedia.org/wiki/Germanium#cite_note-29)

Meanwhile, the demand for germanium for [fiber optic](https://en.wikipedia.org/wiki/Fiber_optics) communication networks, infrared [night vision](https://en.wikipedia.org/wiki/Night_vision) systems, and [polymerization](https://en.wikipedia.org/wiki/Polymerization) [catalysts](https://en.wikipedia.org/wiki/Catalysts) increased dramatically.[[22]](https://en.wikipedia.org/wiki/Germanium#cite_note-acs-25) These end uses represented 85% of worldwide germanium consumption in 2000.[[25]](https://en.wikipedia.org/wiki/Germanium#cite_note-usgs-28) The US government even designated germanium as a strategic and critical material, calling for a 146 [ton](https://en.wikipedia.org/wiki/Short_ton) (132 [t](https://en.wikipedia.org/wiki/Tonne)) supply in the national defense stockpile in 1987.[[22]](https://en.wikipedia.org/wiki/Germanium#cite_note-acs-25)

Germanium differs from silicon in that the supply is limited by the availability of exploitable sources, while the supply of silicon is limited only by production capacity since silicon comes from ordinary sand and [quartz](https://en.wikipedia.org/wiki/Quartz). While silicon could be bought in 1998 for less than $10 per kg,[[22]](https://en.wikipedia.org/wiki/Germanium#cite_note-acs-25) the price of germanium was almost $800 per kg.[[22]](https://en.wikipedia.org/wiki/Germanium#cite_note-acs-25)

**Characteristics**

Under [standard conditions](https://en.wikipedia.org/wiki/Standard_conditions), germanium is a brittle, silvery-white, semi-metallic element.[[27]](https://en.wikipedia.org/wiki/Germanium#cite_note-nbb-30) This form constitutes an [allotrope](https://en.wikipedia.org/wiki/Allotrope) known as *α-germanium*, which has a metallic luster and a [diamond cubic crystal structure](https://en.wikipedia.org/wiki/Diamond_cubic), the same as [diamond](https://en.wikipedia.org/wiki/Diamond).[[25]](https://en.wikipedia.org/wiki/Germanium#cite_note-usgs-28) At pressures above 120 [kbar](https://en.wikipedia.org/wiki/Bar_(unit)), it becomes the allotrope *β-germanium* with the same structure as β-[tin](https://en.wikipedia.org/wiki/Tin).[[28]](https://en.wikipedia.org/wiki/Germanium#cite_note-HollemanAF-31) Like silicon, [gallium](https://en.wikipedia.org/wiki/Gallium), [bismuth](https://en.wikipedia.org/wiki/Bismuth), [antimony](https://en.wikipedia.org/wiki/Antimony), and [water](https://en.wikipedia.org/wiki/Water), germanium is one of the few substances that expands as it solidifies (i.e. [freezes](https://en.wikipedia.org/wiki/Freezing)) from the molten state.[[28]](https://en.wikipedia.org/wiki/Germanium#cite_note-HollemanAF-31)

Germanium is a [semiconductor](https://en.wikipedia.org/wiki/Semiconductor). [Zone refining](https://en.wikipedia.org/wiki/Zone_refining) techniques have led to the production of crystalline germanium for semiconductors that has an impurity of only one part in 1010,[[29]](https://en.wikipedia.org/wiki/Germanium#cite_note-lanl-32) making it one of the purest materials ever obtained.[[30]](https://en.wikipedia.org/wiki/Germanium#cite_note-33) The first metallic material discovered (in 2005) to become a [superconductor](https://en.wikipedia.org/wiki/Superconductor) in the presence of an extremely strong [electromagnetic field](https://en.wikipedia.org/wiki/Electromagnetic_field) was an [alloy of germanium, uranium, and rhodium](https://en.wikipedia.org/wiki/Uranium_rhodium_germanium).[[31]](https://en.wikipedia.org/wiki/Germanium#cite_note-34)

Pure germanium suffers from the forming of [whiskers](https://en.wikipedia.org/wiki/Whisker_(metallurgy)) by spontaneous [screw dislocations](https://en.wikipedia.org/wiki/Screw_dislocation). If a whisker grows long enough to touch another part of the assembly or a metallic packaging, it can effectively [shunt out](https://en.wikipedia.org/wiki/Shunt_(electrical)) a [p-n junction](https://en.wikipedia.org/wiki/P-n_junction). This is one of the primary reasons for the failure of old germanium diodes and transistors.

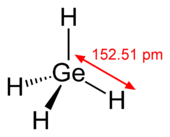
**Chemistry**

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

Elemental germanium oxidizes slowly to [GeO2](https://en.wikipedia.org/wiki/Germanium_dioxide) at 250 °C.[[32]](https://en.wikipedia.org/wiki/Germanium#cite_note-35) Germanium is insoluble in dilute [acids](https://en.wikipedia.org/wiki/Acids) and [alkalis](https://en.wikipedia.org/wiki/Alkalis) but dissolves slowly in hot concentrated sulfuric and nitric acids and reacts violently with molten alkalis to produce [germanates](https://en.wikipedia.org/wiki/Germanate) ([GeO  
3]2−  
). Germanium occurs mostly in the [oxidation state](https://en.wikipedia.org/wiki/Oxidation_state) +4 although many +2 compounds are known.[[33]](https://en.wikipedia.org/wiki/Germanium#cite_note-Greenwood-36) Other oxidation states are rare: +3 is found in compounds such as Ge2Cl6, and +3 and +1 are found on the surface of oxides,[[34]](https://en.wikipedia.org/wiki/Germanium#cite_note-37) or negative oxidation states in [germanes](https://en.wikipedia.org/wiki/Germane), such as −4 in GeH  
4. Germanium cluster anions ([Zintl](https://en.wikipedia.org/wiki/Zintl_phase) ions) such as Ge42−, Ge94−, Ge92−, [(Ge9)2]6− have been prepared by the extraction from alloys containing alkali metals and germanium in liquid ammonia in the presence of [ethylenediamine](https://en.wikipedia.org/wiki/Ethylenediamine) or a [cryptand](https://en.wikipedia.org/wiki/Cryptand).[[33]](https://en.wikipedia.org/wiki/Germanium#cite_note-Greenwood-36)[[35]](https://en.wikipedia.org/wiki/Germanium#cite_note-38) The oxidation states of the element in these ions are not integers—similar to the [ozonides](https://en.wikipedia.org/wiki/Ozonide) O3−.

Two [oxides](https://en.wikipedia.org/wiki/Oxide) of germanium are known: [germanium dioxide](https://en.wikipedia.org/wiki/Germanium_dioxide) (GeO  
2, germania) and [germanium monoxide](https://en.wikipedia.org/wiki/Germanium_monoxide), (GeO).[[28]](https://en.wikipedia.org/wiki/Germanium#cite_note-HollemanAF-31) The dioxide, GeO2 can be obtained by roasting [germanium disulfide](https://en.wikipedia.org/wiki/Germanium_disulfide) (GeS  
2), and is a white powder that is only slightly soluble in water but reacts with alkalis to form germanates.[[28]](https://en.wikipedia.org/wiki/Germanium#cite_note-HollemanAF-31) The monoxide, germanous oxide, can be obtained by the high temperature reaction of GeO2 with Ge metal.[[28]](https://en.wikipedia.org/wiki/Germanium#cite_note-HollemanAF-31) The dioxide (and the related oxides and germanates) exhibits the unusual property of having a high refractive index for visible light, but transparency to [infrared](https://en.wikipedia.org/wiki/Infrared) light.[[36]](https://en.wikipedia.org/wiki/Germanium#cite_note-39)[[37]](https://en.wikipedia.org/wiki/Germanium#cite_note-40) [Bismuth germanate](https://en.wikipedia.org/wiki/Bismuth_germanate), Bi4Ge3O12, (BGO) is used as a [scintillator](https://en.wikipedia.org/wiki/Scintillator).[[38]](https://en.wikipedia.org/wiki/Germanium#cite_note-BGO-41)

[Binary compounds](https://en.wikipedia.org/wiki/Binary_compound) with other [chalcogens](https://en.wikipedia.org/wiki/Chalcogen) are also known, such as the di[sulfide](https://en.wikipedia.org/wiki/Sulfide) (GeS  
2), di[selenide](https://en.wikipedia.org/wiki/Selenide) (GeSe  
2), and the [monosulfide](https://en.wikipedia.org/wiki/Germanium_monosulfide) (GeS), selenide (GeSe), and [telluride](https://en.wikipedia.org/wiki/Telluride_(chemistry)) (GeTe).[[33]](https://en.wikipedia.org/wiki/Germanium#cite_note-Greenwood-36) GeS2 forms as a white precipitate when hydrogen sulfide is passed through strongly acid solutions containing Ge(IV).[[33]](https://en.wikipedia.org/wiki/Germanium#cite_note-Greenwood-36) The disulfide is appreciably soluble in water and in solutions of caustic alkalis or alkaline sulfides. Nevertheless, it is not soluble in acidic water, which allowed Winkler to discover the element.[[39]](https://en.wikipedia.org/wiki/Germanium#cite_note-42) By heating the disulfide in a current of [hydrogen](https://en.wikipedia.org/wiki/Hydrogen), the monosulfide (GeS) is formed, which sublimes in thin plates of a dark color and metallic luster, and is soluble in solutions of the caustic alkalis.[[28]](https://en.wikipedia.org/wiki/Germanium#cite_note-HollemanAF-31) Upon melting with [alkaline carbonates](https://en.wikipedia.org/wiki/Alkali_metal_compound) and [sulfur](https://en.wikipedia.org/wiki/Sulfur), germanium compounds form salts known as thiogermanates.[[40]](https://en.wikipedia.org/wiki/Germanium#cite_note-43)

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

Germane is similar to [methane](https://en.wikipedia.org/wiki/Methane).

Four tetra[halides](https://en.wikipedia.org/wiki/Halides) are known. Under normal conditions GeI4 is a solid, GeF4 a gas and the others volatile liquids. For example, [germanium tetrachloride](https://en.wikipedia.org/wiki/Germanium_tetrachloride), GeCl4, is obtained as a colorless fuming liquid boiling at 83.1 °C by heating the metal with chlorine.[[28]](https://en.wikipedia.org/wiki/Germanium#cite_note-HollemanAF-31) All the tetrahalides are readily hydrolyzed to hydrated germanium dioxide.[[28]](https://en.wikipedia.org/wiki/Germanium#cite_note-HollemanAF-31) GeCl4 is used in the production of organogermanium compounds.[[33]](https://en.wikipedia.org/wiki/Germanium#cite_note-Greenwood-36) All four dihalides are known and in contrast to the tetrahalides are polymeric solids.[[33]](https://en.wikipedia.org/wiki/Germanium#cite_note-Greenwood-36) Additionally Ge2Cl6 and some higher compounds of formula Ge*n*Cl2*n*+2 are known.[[28]](https://en.wikipedia.org/wiki/Germanium#cite_note-HollemanAF-31) The unusual compound Ge6Cl16 has been prepared that contains the Ge5Cl12 unit with a [neopentane](https://en.wikipedia.org/wiki/Neopentane) structure.[[41]](https://en.wikipedia.org/wiki/Germanium#cite_note-44)

[Germane](https://en.wikipedia.org/wiki/Germane) (GeH4) is a compound similar in structure to [methane](https://en.wikipedia.org/wiki/Methane). Polygermanes—compounds that are similar to [alkanes](https://en.wikipedia.org/wiki/Alkane)—with formula Ge*n*H2*n*+2 containing up to five germanium atoms are known.[[33]](https://en.wikipedia.org/wiki/Germanium#cite_note-Greenwood-36) The germanes are less volatile and less reactive than their corresponding silicon analogues.[[33]](https://en.wikipedia.org/wiki/Germanium#cite_note-Greenwood-36) GeH4 reacts with alkali metals in liquid ammonia to form white crystalline MGeH3 which contain the GeH3− [anion](https://en.wikipedia.org/wiki/Anion).[[33]](https://en.wikipedia.org/wiki/Germanium#cite_note-Greenwood-36) The germanium hydrohalides with one, two and three halogen atoms are colorless reactive liquids.[[33]](https://en.wikipedia.org/wiki/Germanium#cite_note-Greenwood-36)

[Skeletal chemical structures outlining an additive chemical reaction including an organogermanium compound.](https://en.wikipedia.org/wiki/File:NucleophilicAdditionWithOrganogermanium.png)

[Nucleophilic](https://en.wikipedia.org/wiki/Nucleophile) addition with an organogermanium compound.

The first [organogermanium compound](https://en.wikipedia.org/wiki/Organogermanium_compound) was synthesized by Winkler in 1887; the reaction of germanium tetrachloride with [diethylzinc](https://en.wikipedia.org/wiki/Diethylzinc) yielded [tetraethylgermane](https://en.wikipedia.org/wiki/Tetraethylgermane) (Ge(C  
2H  
5)  
4).[[7]](https://en.wikipedia.org/wiki/Germanium#cite_note-Winkle2-8) Organogermanes of the type R4Ge (where R is an [alkyl](https://en.wikipedia.org/wiki/Alkyl)) such as [tetramethylgermane](https://en.wikipedia.org/wiki/Tetramethylgermane) (Ge(CH  
3)  
4) and tetraethylgermane are accessed through the cheapest available germanium precursor [germanium tetrachloride](https://en.wikipedia.org/wiki/Germanium_tetrachloride) and alkyl nucleophiles. Organic germanium hydrides such as [isobutylgermane](https://en.wikipedia.org/wiki/Isobutylgermane) ((CH  
3)  
2CHCH  
2GeH  
3) were found to be less hazardous and may be used as a liquid substitute for toxic [germane](https://en.wikipedia.org/wiki/Germane) gas in [semiconductor](https://en.wikipedia.org/wiki/Semiconductor) applications. Many germanium [reactive intermediates](https://en.wikipedia.org/wiki/Reactive_intermediate) are known: [germyl](https://en.wikipedia.org/wiki/-yl) [free radicals](https://en.wikipedia.org/wiki/Free_radical), germylenes (similar to [carbenes](https://en.wikipedia.org/wiki/Carbene)), and germynes (similar to [carbynes](https://en.wikipedia.org/wiki/Carbyne)).[[42]](https://en.wikipedia.org/wiki/Germanium#cite_note-45)[[43]](https://en.wikipedia.org/wiki/Germanium#cite_note-46) The organogermanium compound [2-carboxyethylgermasesquioxane](https://en.wikipedia.org/wiki/Propagermanium) was first reported in the 1970s, and for a while was used as a dietary supplement and thought to possibly have anti-tumor qualities.[[44]](https://en.wikipedia.org/wiki/Germanium#cite_note-toxic-47)

Using a ligand called Eind (1,1,3,3,5,5,7,7-octaethyl-s-hydrindacen-4-yl) germanium is able to form a double bond with oxygen (germanone).[[45]](https://en.wikipedia.org/wiki/Germanium#cite_note-48)

**Isotopes**

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

Germanium occurs in 5 natural [isotopes](https://en.wikipedia.org/wiki/Isotope): 70  
Ge  
, 72  
Ge  
, 73  
Ge  
, 74  
Ge  
, and 76  
Ge  
. Of these, 76  
Ge  
is very slightly radioactive, decaying by [double beta decay](https://en.wikipedia.org/wiki/Double_beta_decay) with a [half-life](https://en.wikipedia.org/wiki/Half-life) of 1.78×1021 years. 74  
Ge  
is the most common isotope, having a [natural abundance](https://en.wikipedia.org/wiki/Natural_abundance) of approximately 36%. 76  
Ge  
is the least common with a natural abundance of approximately 7%.[[46]](https://en.wikipedia.org/wiki/Germanium#cite_note-nubase-49) When bombarded with alpha particles, the isotope 72  
Ge  
will generate stable [77  
Se](https://en.wikipedia.org/wiki/Selenium-77), releasing high energy electrons in the process.[[47]](https://en.wikipedia.org/wiki/Germanium#cite_note-72Ge-50) Because of this, it is used in combination with [radon](https://en.wikipedia.org/wiki/Radon) for [nuclear batteries](https://en.wikipedia.org/wiki/Atomic_battery).[[47]](https://en.wikipedia.org/wiki/Germanium#cite_note-72Ge-50)

At least 27 [radioisotopes](https://en.wikipedia.org/wiki/Radioisotope) have also been synthesized, ranging in atomic mass from 58 to 89. The most stable of these is 68  
Ge  
, decaying by [electron capture](https://en.wikipedia.org/wiki/Electron_capture) with a half-life of 270.95 days. The least stable is 60  
Ge  
, with a half-life of 30 [ms](https://en.wikipedia.org/wiki/Millisecond). While most of germanium's radioisotopes decay by [beta decay](https://en.wikipedia.org/wiki/Beta_decay), 61  
Ge  
and 64  
Ge  
decay by  [β+](https://en.wikipedia.org/wiki/Positron_emission)delayed [proton emission](https://en.wikipedia.org/wiki/Proton_emission).[[46]](https://en.wikipedia.org/wiki/Germanium#cite_note-nubase-49) 84  
Ge  
through 87  
Ge  
isotopes also exhibit minor  [β−](https://en.wikipedia.org/wiki/Beta_decay)delayed [neutron emission](https://en.wikipedia.org/wiki/Neutron_emission) decay paths.[[46]](https://en.wikipedia.org/wiki/Germanium#cite_note-nubase-49)

**Occurrence**

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

Germanium is created by [stellar nucleosynthesis](https://en.wikipedia.org/wiki/Stellar_nucleosynthesis), mostly by the [s-process](https://en.wikipedia.org/wiki/S-process) in [asymptotic giant branch](https://en.wikipedia.org/wiki/Asymptotic_giant_branch) stars. The s-process is a slow [neutron](https://en.wikipedia.org/wiki/Neutron) capture of lighter elements inside pulsating [red giant](https://en.wikipedia.org/wiki/Red_giant) stars.[[48]](https://en.wikipedia.org/wiki/Germanium#cite_note-sterling-51) Germanium has been detected in some of the most distant stars[[49]](https://en.wikipedia.org/wiki/Germanium#cite_note-52) and in the atmosphere of Jupiter.[[50]](https://en.wikipedia.org/wiki/Germanium#cite_note-53)

Germanium's abundance [in the Earth's crust](https://en.wikipedia.org/wiki/Earth#Chemical_composition) is approximately 1.6 [ppm](https://en.wikipedia.org/wiki/Parts_per_million).[[51]](https://en.wikipedia.org/wiki/Germanium#cite_note-Holl-54) Only a few minerals like [argyrodite](https://en.wikipedia.org/wiki/Argyrodite), [briartite](https://en.wikipedia.org/wiki/Briartite), [germanite](https://en.wikipedia.org/wiki/Germanite), and [renierite](https://en.wikipedia.org/wiki/Renierite) contain appreciable amounts of germanium.[[25]](https://en.wikipedia.org/wiki/Germanium#cite_note-usgs-28)[[52]](https://en.wikipedia.org/wiki/Germanium#cite_note-55) Only few of them (especially germanite) are, very rarely, found in mineable amounts.[[53]](https://en.wikipedia.org/wiki/Germanium#cite_note-56)[[54]](https://en.wikipedia.org/wiki/Germanium#cite_note-57)[[55]](https://en.wikipedia.org/wiki/Germanium#cite_note-58) Some zinc-copper-lead ore bodies contain enough germanium to justify extraction from the final ore concentrate.[[51]](https://en.wikipedia.org/wiki/Germanium#cite_note-Holl-54) An unusual natural enrichment process causes a high content of germanium in some coal seams, discovered by [Victor Moritz Goldschmidt](https://en.wikipedia.org/wiki/Victor_Moritz_Goldschmidt) during a broad survey for germanium deposits.[[56]](https://en.wikipedia.org/wiki/Germanium#cite_note-Gold1-59)[[57]](https://en.wikipedia.org/wiki/Germanium#cite_note-Gold2-60) The highest concentration ever found was in [Hartley](https://en.wikipedia.org/wiki/Hartley,_Northumberland) coal ash with as much as 1.6% germanium.[[56]](https://en.wikipedia.org/wiki/Germanium#cite_note-Gold1-59)[[57]](https://en.wikipedia.org/wiki/Germanium#cite_note-Gold2-60) The coal deposits near [Xilinhaote](https://en.wikipedia.org/wiki/Xilinhaote), [Inner Mongolia](https://en.wikipedia.org/wiki/Inner_Mongolia), contain an estimated 1600 [tonnes](https://en.wikipedia.org/wiki/Tonne) of germanium.[[51]](https://en.wikipedia.org/wiki/Germanium#cite_note-Holl-54)

**Production**

[](https://en.wikipedia.org/wiki/File:Renierit.JPG)

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

About 118 [tonnes](https://en.wikipedia.org/wiki/Tonne) of germanium was produced in 2011 worldwide, mostly in China (80 t), Russia (5 t) and United States (3 t).[[25]](https://en.wikipedia.org/wiki/Germanium#cite_note-usgs-28) Germanium is recovered as a by-product from [sphalerite](https://en.wikipedia.org/wiki/Sphalerite) [zinc](https://en.wikipedia.org/wiki/Zinc) ores where it is concentrated in amounts as great as 0.3%,[[58]](https://en.wikipedia.org/wiki/Germanium#cite_note-61) especially from low-temperature sediment-hosted, massive [Zn](https://en.wikipedia.org/wiki/Zinc)–[Pb](https://en.wikipedia.org/wiki/Lead)–[Cu](https://en.wikipedia.org/wiki/Copper)(–[Ba](https://en.wikipedia.org/wiki/Barium)) deposits and carbonate-hosted Zn–Pb deposits.[[59]](https://en.wikipedia.org/wiki/Germanium#cite_note-62) A recent study found that at least 10,000 t of extractable germanium is contained in known zinc reserves, particularly those hosted by [Mississippi-Valley type deposits](https://en.wikipedia.org/wiki/Carbonate-hosted_lead-zinc_ore_deposits), while at least 112,000 t will be found in coal reserves.[[60]](https://en.wikipedia.org/wiki/Germanium#cite_note-63)[[61]](https://en.wikipedia.org/wiki/Germanium#cite_note-64) In 2007 35% of the demand was met by recycled germanium.[[51]](https://en.wikipedia.org/wiki/Germanium#cite_note-Holl-54)

While it is produced mainly from [sphalerite](https://en.wikipedia.org/wiki/Sphalerite), it is also found in [silver](https://en.wikipedia.org/wiki/Silver), [lead](https://en.wikipedia.org/wiki/Lead), and [copper](https://en.wikipedia.org/wiki/Copper) ores. Another source of germanium is [fly ash](https://en.wikipedia.org/wiki/Fly_ash) of power plants fueled from coal deposits that contain germanium. Russia and China used this as a source for germanium.[[62]](https://en.wikipedia.org/wiki/Germanium#cite_note-Naumov-65) Russia's deposits are located in the far east of [Sakhalin](https://en.wikipedia.org/wiki/Sakhalin) Island, and northeast of [Vladivostok](https://en.wikipedia.org/wiki/Vladivostok). The deposits in China are located mainly in the [lignite](https://en.wikipedia.org/wiki/Lignite) mines near [Lincang](https://en.wikipedia.org/wiki/Lincang), [Yunnan](https://en.wikipedia.org/wiki/Yunnan); coal is also mined near [Xilinhaote](https://en.wikipedia.org/wiki/Xilinhaote), [Inner Mongolia](https://en.wikipedia.org/wiki/Inner_Mongolia).[[51]](https://en.wikipedia.org/wiki/Germanium#cite_note-Holl-54)

|  |  |
| --- | --- |
| **Year** | **Cost (**[**$**](https://en.wikipedia.org/wiki/United_States_dollar)**/kg)**[**[63]**](https://en.wikipedia.org/wiki/Germanium#cite_note-66) |
| 1999 | 1,400 |
| 2000 | 1,250 |
| 2001 | 890 |
| 2002 | 620 |
| 2003 | 380 |
| 2004 | 600 |
| 2005 | 660 |
| 2006 | 880 |
| 2007 | 1,240 |
| 2008 | 1,490 |
| 2009 | 950 |
| 2010 | 940 |
| 2011 | 1,625 |
| 2012 | 1,680 |
| 2013 | 1,875 |
| 2014 | 1,900 |
| 2015 | 1,760 |
| 2016 | 950 |

The ore concentrates are mostly [sulfidic](https://en.wikipedia.org/wiki/Sulfide); they are converted to the [oxides](https://en.wikipedia.org/wiki/Oxide) by heating under air in a process known as [roasting](https://en.wikipedia.org/wiki/Roasting_(metallurgy)):

GeS2 + 3 O2 → GeO2 + 2 SO2

Some of the germanium is left in the dust produced, while the rest is converted to germanates, which are then leached (together with zinc) from the cinder by sulfuric acid. After neutralization, only the zinc stays in solution while germanium and other metals precipitate. After removing some of the zinc in the precipitate by the [Waelz process](https://en.wikipedia.org/wiki/Waelz_process), the residing Waelz oxide is leached a second time. The [dioxide](https://en.wikipedia.org/wiki/Germanium_dioxide) is obtained as precipitate and converted with [chlorine](https://en.wikipedia.org/wiki/Chlorine) gas or hydrochloric acid to [germanium tetrachloride](https://en.wikipedia.org/wiki/Germanium_tetrachloride), which has a low boiling point and can be isolated by distillation:[[62]](https://en.wikipedia.org/wiki/Germanium#cite_note-Naumov-65)

GeO2 + 4 HCl → GeCl4 + 2 H2O

GeO2 + 2 Cl2 → GeCl4 + O2

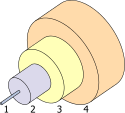
Germanium tetrachloride is either hydrolyzed to the oxide (GeO2) or purified by fractional distillation and then hydrolyzed.[[62]](https://en.wikipedia.org/wiki/Germanium#cite_note-Naumov-65) The highly pure GeO2 is now suitable for the production of germanium glass. It is reduced to the element by reacting it with hydrogen, producing germanium suitable for infrared optics and semiconductor production:

GeO2 + 2 H2 → Ge + 2 H2O

The germanium for steel production and other industrial processes is normally reduced using carbon:[[64]](https://en.wikipedia.org/wiki/Germanium#cite_note-Moska-67)

GeO2 + C → Ge + CO2

**Applications**

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

A typical single-mode optical fiber. Germanium oxide is a [dopant](https://en.wikipedia.org/wiki/Dopant) of the core silica (Item 1).  
1. Core 8 µm  
2. Cladding 125 µm  
3. Buffer 250 µm  
4. Jacket 400 µm

The major end uses for germanium in 2007, worldwide, were estimated to be: 35% for [fiber-optics](https://en.wikipedia.org/wiki/Fiber-optic), 30% [infrared optics](https://en.wikipedia.org/wiki/Infrared_vision), 15% [polymerization](https://en.wikipedia.org/wiki/Polymerization) catalysts, and 15% electronics and solar electric applications.[[25]](https://en.wikipedia.org/wiki/Germanium#cite_note-usgs-28) The remaining 5% went into such uses as phosphors, metallurgy, and chemotherapy.[[25]](https://en.wikipedia.org/wiki/Germanium#cite_note-usgs-28)

**Optics**

The notable properties of [germania](https://en.wikipedia.org/wiki/Germanium_dioxide) (GeO2) are its high [index of refraction](https://en.wikipedia.org/wiki/Refractive_index) and its low [optical dispersion](https://en.wikipedia.org/wiki/Dispersion_(optics)). These make it especially useful for [wide-angle camera lenses](https://en.wikipedia.org/wiki/Wide-angle_camera_lens), [microscopy](https://en.wikipedia.org/wiki/Microscopy), and the core part of [optical fibers](https://en.wikipedia.org/wiki/Optical_fiber).[[65]](https://en.wikipedia.org/wiki/Germanium#cite_note-68)[[66]](https://en.wikipedia.org/wiki/Germanium#cite_note-Brown-69) It has replaced [titania](https://en.wikipedia.org/wiki/Titanium_dioxide) as the [dopant](https://en.wikipedia.org/wiki/Dopant) for silica fiber, eliminating the subsequent heat treatment that made the fibers brittle.[[67]](https://en.wikipedia.org/wiki/Germanium#cite_note-70) At the end of 2002, the fiber optics industry consumed 60% of the annual germanium use in the United States, but this is less than 10% of worldwide consumption.[[66]](https://en.wikipedia.org/wiki/Germanium#cite_note-Brown-69) [GeSbTe](https://en.wikipedia.org/wiki/GeSbTe) is a [phase change material](https://en.wikipedia.org/wiki/Phase_change_material) used for its optic properties, such as that used in [rewritable DVDs](https://en.wikipedia.org/wiki/DVD-RW).[[68]](https://en.wikipedia.org/wiki/Germanium#cite_note-71)

Because germanium is transparent in the infrared wavelengths, it is an important [infrared](https://en.wikipedia.org/wiki/Infrared) optical material that can be readily cut and polished into lenses and windows. It is especially used as the front optic in [thermal imaging cameras](https://en.wikipedia.org/wiki/Thermographic_camera) working in the 8 to 14 [micron](https://en.wikipedia.org/wiki/Micrometre) range for passive thermal imaging and for hot-spot detection in military, mobile [night vision](https://en.wikipedia.org/wiki/Night_vision), and fire fighting applications.[[64]](https://en.wikipedia.org/wiki/Germanium#cite_note-Moska-67) It is used in infrared [spectroscopes](https://en.wikipedia.org/wiki/Spectroscope) and other optical equipment that require extremely sensitive [infrared detectors](https://en.wikipedia.org/wiki/Infrared_photography).[[66]](https://en.wikipedia.org/wiki/Germanium#cite_note-Brown-69) It has a very high [refractive index](https://en.wikipedia.org/wiki/Refractive_index) (4.0) and must be coated with anti-reflection agents. Particularly, a very hard special antireflection coating of [diamond-like carbon](https://en.wikipedia.org/wiki/Diamond-like_carbon) (DLC), refractive index 2.0, is a good match and produces a diamond-hard surface that can withstand much environmental abuse.[[69]](https://en.wikipedia.org/wiki/Germanium#cite_note-72)[[70]](https://en.wikipedia.org/wiki/Germanium#cite_note-73)

**Electronics**

[Silicon-germanium](https://en.wikipedia.org/wiki/Silicon-germanium) alloys are rapidly becoming an important semiconductor material for high-speed integrated circuits. Circuits utilizing the properties of Si-SiGe junctions can be much faster than those using silicon alone.[[71]](https://en.wikipedia.org/wiki/Germanium#cite_note-74) Silicon-germanium is beginning to replace [gallium arsenide](https://en.wikipedia.org/wiki/Gallium_arsenide) (GaAs) in wireless communications devices.[[25]](https://en.wikipedia.org/wiki/Germanium#cite_note-usgs-28) The SiGe chips, with high-speed properties, can be made with low-cost, well-established production techniques of the [silicon chip](https://en.wikipedia.org/wiki/Silicon_chip) industry.[[25]](https://en.wikipedia.org/wiki/Germanium#cite_note-usgs-28)

[Solar panels](https://en.wikipedia.org/wiki/Solar_panel) are a major use of germanium. Germanium is the substrate of the wafers for high-efficiency [multijunction photovoltaic cells](https://en.wikipedia.org/wiki/Multijunction_photovoltaic_cell) for space applications. High-brightness LEDs, used for automobile headlights and to backlight LCD screens, are an important application.[[25]](https://en.wikipedia.org/wiki/Germanium#cite_note-usgs-28)

Because germanium and [gallium arsenide](https://en.wikipedia.org/wiki/Gallium_arsenide) have very similar lattice constants, germanium substrates can be used to make gallium arsenide [solar cells](https://en.wikipedia.org/wiki/Solar_cell).[[72]](https://en.wikipedia.org/wiki/Germanium#cite_note-75) The [Mars Exploration Rovers](https://en.wikipedia.org/wiki/Mars_Exploration_Rover) and several satellites use triple junction gallium arsenide on germanium cells.[[73]](https://en.wikipedia.org/wiki/Germanium#cite_note-76)

Germanium-on-insulator substrates are seen as a potential replacement for silicon on miniaturized chips.[[25]](https://en.wikipedia.org/wiki/Germanium#cite_note-usgs-28) Other uses in electronics include [phosphors](https://en.wikipedia.org/wiki/Phosphor) in [fluorescent lamps](https://en.wikipedia.org/wiki/Fluorescent_lamp)[[29]](https://en.wikipedia.org/wiki/Germanium#cite_note-lanl-32) and solid-state light-emitting diodes (LEDs).[[25]](https://en.wikipedia.org/wiki/Germanium#cite_note-usgs-28) Germanium transistors are still used in some [effects pedals](https://en.wikipedia.org/wiki/Effects_pedal) by musicians who wish to reproduce the distinctive tonal character of the ["fuzz"-tone](https://en.wikipedia.org/wiki/Distortion_(music)) from the early [rock and roll](https://en.wikipedia.org/wiki/Rock_and_roll) era, most notably the [Dallas Arbiter Fuzz Face](https://en.wikipedia.org/wiki/Fuzz_Face).[[74]](https://en.wikipedia.org/wiki/Germanium#cite_note-77)

**Other uses**

[](https://en.wikipedia.org/wiki/File:Pet_Flasche.JPG)

A [PET](https://en.wikipedia.org/wiki/Polyethylene_terephthalate) [bottle](https://en.wikipedia.org/wiki/Bottle)

Germanium dioxide is also used in [catalysts](https://en.wikipedia.org/wiki/Catalyst) for [polymerization](https://en.wikipedia.org/wiki/Polymerization) in the production of [polyethylene terephthalate](https://en.wikipedia.org/wiki/Polyethylene_terephthalate) (PET).[[75]](https://en.wikipedia.org/wiki/Germanium#cite_note-Thiele-78) The high brilliance of this polyester is especially favored for PET bottles marketed in Japan.[[75]](https://en.wikipedia.org/wiki/Germanium#cite_note-Thiele-78) In the United States, germanium is not used for polymerization catalysts.[[25]](https://en.wikipedia.org/wiki/Germanium#cite_note-usgs-28)

Due to the similarity between silica (SiO2) and germanium dioxide (GeO2), the silica stationary phase in some [gas chromatography](https://en.wikipedia.org/wiki/Gas_chromatography) columns can be replaced by GeO2.[[76]](https://en.wikipedia.org/wiki/Germanium#cite_note-79)

In recent years germanium has seen increasing use in precious metal alloys. In [sterling silver](https://en.wikipedia.org/wiki/Sterling_silver) alloys, for instance, it reduces [firescale](https://en.wikipedia.org/wiki/Firescale), increases tarnish resistance, and improves precipitation hardening. A tarnish-proof silver alloy trademarked [Argentium](https://en.wikipedia.org/wiki/Argentium_sterling_silver) contains 1.2% germanium.[[25]](https://en.wikipedia.org/wiki/Germanium#cite_note-usgs-28)

[Semiconductor detectors](https://en.wikipedia.org/wiki/Semiconductor_detector#Germanium_detector) made of single crystal high-purity germanium can precisely identify radiation sources—for example in airport security.[[77]](https://en.wikipedia.org/wiki/Germanium#cite_note-80) Germanium is useful for [monochromators](https://en.wikipedia.org/wiki/Crystal_monochromator) for [beamlines](https://en.wikipedia.org/wiki/Beamline) used in [single crystal](https://en.wikipedia.org/wiki/Single_crystal) [neutron scattering](https://en.wikipedia.org/wiki/Neutron_scattering) and [synchrotron X-ray](https://en.wikipedia.org/wiki/Synchrotron_light) diffraction. The reflectivity has advantages over silicon in neutron and [high energy X-ray](https://en.wikipedia.org/wiki/High_energy_X-rays) applications.[[78]](https://en.wikipedia.org/wiki/Germanium#cite_note-81) Crystals of high purity germanium are used in detectors for [gamma spectroscopy](https://en.wikipedia.org/wiki/Gamma_spectroscopy) and the search for [dark matter](https://en.wikipedia.org/wiki/Dark_matter).[[79]](https://en.wikipedia.org/wiki/Germanium#cite_note-82) Germanium crystals are also used in X-ray spectrometers for the determination of phosphorus, chlorine and sulfur.[[80]](https://en.wikipedia.org/wiki/Germanium#cite_note-83)

Germanium is emerging as an important material for [spintronics](https://en.wikipedia.org/wiki/Spintronics) and spin-based [quantum computing](https://en.wikipedia.org/wiki/Quantum_computing) applications. In 2010, researchers demonstrated room temperature spin transport [[81]](https://en.wikipedia.org/wiki/Germanium#cite_note-84) and more recently donor electron spins in germanium has been shown to have very long [coherence times](https://en.wikipedia.org/wiki/Coherence_time).[[82]](https://en.wikipedia.org/wiki/Germanium#cite_note-85)

**Germanium and health**

Germanium is not considered essential to the health of plants or animals.[[83]](https://en.wikipedia.org/wiki/Germanium#cite_note-American_Cancer_Society-86) Germanium in the environment has little or no health impact. This is primarily because it usually occurs only as a trace element in ores and [carbonaceous](https://en.wikipedia.org/wiki/Carbon) materials, and the various industrial and electronic applications involve very small quantities that are not likely to be ingested.[[25]](https://en.wikipedia.org/wiki/Germanium#cite_note-usgs-28) For similar reasons, end-use germanium has little impact on the environment as a biohazard. Some reactive intermediate compounds of germanium are poisonous (see precautions, below).[[84]](https://en.wikipedia.org/wiki/Germanium#cite_note-Brown_Jr-87)

Germanium supplements, made from both organic and inorganic germanium, have been marketed as an [alternative medicine](https://en.wikipedia.org/wiki/Alternative_medicine) capable of treating [leukemia](https://en.wikipedia.org/wiki/Leukemia) and [lung cancer](https://en.wikipedia.org/wiki/Lung_cancer).[[22]](https://en.wikipedia.org/wiki/Germanium#cite_note-acs-25) There is, however, no [medical evidence](https://en.wikipedia.org/wiki/Evidence-based_medicine) of benefit; some evidence suggests that such supplements are actively harmful.[[83]](https://en.wikipedia.org/wiki/Germanium#cite_note-American_Cancer_Society-86)

Some germanium compounds have been administered by alternative medical practitioners as non-FDA-allowed injectable solutions. Soluble inorganic forms of germanium used at first, notably the citrate-lactate salt, resulted in some cases of [renal](https://en.wikipedia.org/wiki/Renal) dysfunction, [hepatic steatosis](https://en.wikipedia.org/wiki/Hepatic_steatosis), and peripheral [neuropathy](https://en.wikipedia.org/wiki/Neuropathy) in individuals using them over a long term. Plasma and urine germanium concentrations in these individuals, several of whom died, were several orders of magnitude greater than [endogenous](https://en.wikipedia.org/wiki/Endogenous) levels. A more recent organic form, beta-carboxyethylgermanium sesquioxide ([propagermanium](https://en.wikipedia.org/wiki/Propagermanium)), has not exhibited the same spectrum of toxic effects.[[85]](https://en.wikipedia.org/wiki/Germanium#cite_note-88)

[U.S. Food and Drug Administration](https://en.wikipedia.org/wiki/U.S._Food_and_Drug_Administration) research has concluded that inorganic germanium, when used as a [nutritional supplement](https://en.wikipedia.org/wiki/Nutritional_supplement), "presents potential human [health hazard](https://en.wikipedia.org/wiki/Health_hazard)".[[44]](https://en.wikipedia.org/wiki/Germanium#cite_note-toxic-47)

Certain compounds of germanium have low toxicity to [mammals](https://en.wikipedia.org/wiki/Mammal), but have toxic effects against certain [bacteria](https://en.wikipedia.org/wiki/Bacterium).[[27]](https://en.wikipedia.org/wiki/Germanium#cite_note-nbb-30)

**Precautions for chemically reactive germanium compounds**

Some of germanium's artificially-produced compounds are quite reactive and present an immediate hazard to human health on exposure. For example, [germanium chloride](https://en.wikipedia.org/wiki/Germanium_tetrachloride) and [germane](https://en.wikipedia.org/wiki/Germane) (GeH4) are a liquid and gas, respectively, that can be very irritating to the eyes, skin, lungs, and throat.[[86]](https://en.wikipedia.org/wiki/Germanium#cite_note-Gerber_1997_141–146-89)

**Future**

As of the year 2000, about 15% of [United States](https://en.wikipedia.org/wiki/United_States) consumption of germanium was used for infrared optics technology and 50% for fiber-optics. Over the past 20 years, infrared use has consistently decreased; fiber optic demand, however, is slowly increasing. In America, 30–50% of current fiber optic lines are unused [dark fiber](https://en.wikipedia.org/wiki/Dark_fiber), sparking discussion of over-production and a future reduction in demand. Worldwide, demand is increasing dramatically as countries such as China are installing fiber optic telecommunication lines throughout the country.[[87]](https://en.wikipedia.org/wiki/Germanium#cite_note-90)

**See also**

* [Transistor](https://en.wikipedia.org/wiki/Transistor)
* [Vitrain](https://en.wikipedia.org/wiki/Vitrain)

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**Footnotes**

 From Greek, *argyrodite* means *silver-containing*.[[6]](https://en.wikipedia.org/wiki/Germanium#cite_note-6)

  Just as the existence of the new element had been predicted, the existence of the planet [Neptune](https://en.wikipedia.org/wiki/Neptune) had been predicted in about 1843 by the two mathematicians [John Couch Adams](https://en.wikipedia.org/wiki/John_Couch_Adams) and [Urbain Le Verrier](https://en.wikipedia.org/wiki/Urbain_Le_Verrier), using the calculation methods of [celestial mechanics](https://en.wikipedia.org/wiki/Celestial_mechanics). They did this in attempts to explain the fact that the planet [Uranus](https://en.wikipedia.org/wiki/Uranus), upon very close observation, appeared to be being pulled slightly out of position in the sky.[[9]](https://en.wikipedia.org/wiki/Germanium#cite_note-10) [James Challis](https://en.wikipedia.org/wiki/James_Challis) started searching for it in July 1846, and he sighted this planet on September 23, 1846.[[10]](https://en.wikipedia.org/wiki/Germanium#cite_note-11)

* 1.  R. Hermann published claims in 1877 of his discovery of a new element beneath [tantalum](https://en.wikipedia.org/wiki/Tantalum) in the periodic table, which he named *neptunium*, after the Greek god of the oceans and seas.[[11]](https://en.wikipedia.org/wiki/Germanium#cite_note-13)[[12]](https://en.wikipedia.org/wiki/Germanium#cite_note-14) However this [metal](https://en.wikipedia.org/wiki/Metal) was later recognized to be an [alloy](https://en.wikipedia.org/wiki/Alloy) of the elements [niobium](https://en.wikipedia.org/wiki/Niobium) and tantalum.[[13]](https://en.wikipedia.org/wiki/Germanium#cite_note-15) The name "[neptunium](https://en.wikipedia.org/wiki/Neptunium)" was much later given to the synthetic element one step past [uranium](https://en.wikipedia.org/wiki/Uranium) in the Periodic Table, which was discovered by [nuclear physics](https://en.wikipedia.org/wiki/Nuclear_physics) researchers in 1940.[[14]](https://en.wikipedia.org/wiki/Germanium#cite_note-16)

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