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**Scandium**

From Wikipedia, the free encyclopedia

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

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

"Element 21" redirects here. For the golf company, see [Element 21 (company)](https://en.wikipedia.org/wiki/Element_21_(company)).

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| --- | --- |
| Scandium,  21Sc | |
| [Scandium sublimed dendritic and 1cm3 cube.jpg](https://en.wikipedia.org/wiki/File:Scandium_sublimed_dendritic_and_1cm3_cube.jpg) | |
| **General properties** | |
| **Pronunciation** | [/ˈskændiəm/](https://en.wikipedia.org/wiki/Help:IPA/English) ​([*SKAN-dee-əm*](https://en.wikipedia.org/wiki/Help:Pronunciation_respelling_key)) |
| **Appearance** | silvery white |
| [**Standard atomic weight**](https://en.wikipedia.org/wiki/Standard_atomic_weight) **(*A*r, standard)** | 44.955908(5)[[1]](https://en.wikipedia.org/wiki/Scandium#cite_note-CIAAW2016-1) |
| **Scandium 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 |  | | | | | | | | | | | | | | [Titanium](https://en.wikipedia.org/wiki/Titanium) | [Vanadium](https://en.wikipedia.org/wiki/Vanadium) | [Chromium](https://en.wikipedia.org/wiki/Chromium) | [Manganese](https://en.wikipedia.org/wiki/Manganese) | [Iron](https://en.wikipedia.org/wiki/Iron) | [Cobalt](https://en.wikipedia.org/wiki/Cobalt) | [Nickel](https://en.wikipedia.org/wiki/Nickel) | [Copper](https://en.wikipedia.org/wiki/Copper) | [Zinc](https://en.wikipedia.org/wiki/Zinc) | [Gallium](https://en.wikipedia.org/wiki/Gallium) | [Germanium](https://en.wikipedia.org/wiki/Germanium) | [Arsenic](https://en.wikipedia.org/wiki/Arsenic) | [Selenium](https://en.wikipedia.org/wiki/Selenium) | [Bromine](https://en.wikipedia.org/wiki/Bromine) | [Krypton](https://en.wikipedia.org/wiki/Krypton) | | [Rubidium](https://en.wikipedia.org/wiki/Rubidium) | [Strontium](https://en.wikipedia.org/wiki/Strontium) | [Yttrium](https://en.wikipedia.org/wiki/Yttrium) |  |  | | | | | | | | | | | | | [Zirconium](https://en.wikipedia.org/wiki/Zirconium) | [Niobium](https://en.wikipedia.org/wiki/Niobium) | [Molybdenum](https://en.wikipedia.org/wiki/Molybdenum) | [Technetium](https://en.wikipedia.org/wiki/Technetium) | [Ruthenium](https://en.wikipedia.org/wiki/Ruthenium) | [Rhodium](https://en.wikipedia.org/wiki/Rhodium) | [Palladium](https://en.wikipedia.org/wiki/Palladium) | [Silver](https://en.wikipedia.org/wiki/Silver) | [Cadmium](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) | 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[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) | | – ↑ **Sc** ↓ [Y](https://en.wikipedia.org/wiki/Yttrium) | | [calcium](https://en.wikipedia.org/wiki/Calcium) ← **scandium** → [titanium](https://en.wikipedia.org/wiki/Titanium) | | | | |
| [**Atomic number**](https://en.wikipedia.org/wiki/Atomic_number)(*Z*) | 21 |
| [**Group**](https://en.wikipedia.org/wiki/Group_(periodic_table)) | [group 3](https://en.wikipedia.org/wiki/Group_3_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)] 3d1 4s2 |
| Electrons per shell | 2, 8, 9, 2 |
| **Physical properties** | |
| [**Phase**](https://en.wikipedia.org/wiki/Phase_(matter)) **at**[**STP**](https://en.wikipedia.org/wiki/Standard_conditions_for_temperature_and_pressure) | [solid](https://en.wikipedia.org/wiki/Solid) |
| [**Melting point**](https://en.wikipedia.org/wiki/Melting_point) | 1814 [K](https://en.wikipedia.org/wiki/Kelvin) ​(1541 °C, ​2806 °F) |
| [**Boiling point**](https://en.wikipedia.org/wiki/Boiling_point) | 3109 K ​(2836 °C, ​5136 °F) |
| [**Density**](https://en.wikipedia.org/wiki/Density)(near r.t.) | 2.985 g/cm3 |
| when liquid (at m.p.) | 2.80 g/cm3 |
| [**Heat of fusion**](https://en.wikipedia.org/wiki/Enthalpy_of_fusion) | 14.1 [kJ/mol](https://en.wikipedia.org/wiki/Kilojoule_per_mole) |
| [**Heat of vaporization**](https://en.wikipedia.org/wiki/Enthalpy_of_vaporization) | 332.7 kJ/mol |
| [**Molar heat capacity**](https://en.wikipedia.org/wiki/Molar_heat_capacity) | 25.52 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) | 1645 | 1804 | (2006) | (2266) | (2613) | (3101) | | |
| **Atomic properties** | |
| [**Oxidation states**](https://en.wikipedia.org/wiki/Oxidation_state) | +1,[[2]](https://en.wikipedia.org/wiki/Scandium#cite_note-Smith-2) +2,[[3]](https://en.wikipedia.org/wiki/Scandium#cite_note-McGuire-3) **+3** (an [amphoteric](https://en.wikipedia.org/wiki/Amphoterism) oxide) |
| [**Electronegativity**](https://en.wikipedia.org/wiki/Electronegativity) | Pauling scale: 1.36 |
| [**Ionization energies**](https://en.wikipedia.org/wiki/Ionization_energy) | * 1st: 633.1 kJ/mol * 2nd: 1235.0 kJ/mol * 3rd: 2388.6 kJ/mol * ([more](https://en.wikipedia.org/wiki/Molar_ionization_energies_of_the_elements#scandium)) |
| [**Atomic radius**](https://en.wikipedia.org/wiki/Atomic_radius) | empirical: 162 [pm](https://en.wikipedia.org/wiki/Picometre) |
| [**Covalent radius**](https://en.wikipedia.org/wiki/Covalent_radius) | 170±7 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:Scandium_spectrum_visible.png)  [**Spectral lines**](https://en.wikipedia.org/wiki/Spectral_line) **of scandium** | |
| **Other properties** | |
| [**Crystal structure**](https://en.wikipedia.org/wiki/Crystal_structure) | ​[hexagonal close-packed](https://en.wikipedia.org/wiki/Close-packing_of_equal_spheres) (hcp)  [Hexagonal close packed crystal structure for scandium](https://en.wikipedia.org/wiki/File:Hexagonal_close_packed.svg) |
| [**Thermal expansion**](https://en.wikipedia.org/wiki/Coefficient_of_thermal_expansion) | α, poly: 10.2 µm/(m·K) (at r.t.) |
| [**Thermal conductivity**](https://en.wikipedia.org/wiki/Thermal_conductivity) | 15.8 W/(m·K) |
| [**Electrical resistivity**](https://en.wikipedia.org/wiki/Electrical_resistivity_and_conductivity) | α, poly: 562 nΩ·m (at r.t., calculated) |
| [**Magnetic ordering**](https://en.wikipedia.org/wiki/Magnetism) | paramagnetic |
| [**Magnetic susceptibility**](https://en.wikipedia.org/wiki/Magnetic_susceptibility) | +315.0·10−6 cm3/mol (292 K)[[4]](https://en.wikipedia.org/wiki/Scandium#cite_note-4) |
| [**Young's modulus**](https://en.wikipedia.org/wiki/Young%27s_modulus) | 74.4 GPa |
| [**Shear modulus**](https://en.wikipedia.org/wiki/Shear_modulus) | 29.1 GPa |
| [**Bulk modulus**](https://en.wikipedia.org/wiki/Bulk_modulus) | 56.6 GPa |
| [**Poisson ratio**](https://en.wikipedia.org/wiki/Poisson%27s_ratio) | 0.279 |
| [**Brinell hardness**](https://en.wikipedia.org/wiki/Brinell_hardness_test) | 736–1200 MPa |
| [**CAS Number**](https://en.wikipedia.org/wiki/CAS_Registry_Number) | 7440-20-2 |
| **History** | |
| **Naming** | after [Scandinavia](https://en.wikipedia.org/wiki/Scandinavia) |
| **Prediction** | [Dmitri Mendeleev](https://en.wikipedia.org/wiki/Dmitri_Mendeleev) (1871) |
| [**Discovery**](https://en.wikipedia.org/wiki/Timeline_of_chemical_element_discoveries) **and first isolation** | [Lars Fredrik Nilson](https://en.wikipedia.org/wiki/Lars_Fredrik_Nilson) (1879) |
| **Main** [**isotopes of scandium**](https://en.wikipedia.org/wiki/Isotopes_of_scandium) | |
| |  |  |  |  |  | | --- | --- | --- | --- | --- | | [**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) | | **44**[**m**](https://en.wikipedia.org/wiki/Nuclear_isomer)**2Sc** | [syn](https://en.wikipedia.org/wiki/Synthetic_radioisotope) | 58.61 h | [IT](https://en.wikipedia.org/wiki/Internal_conversion) | 44Sc | | [γ](https://en.wikipedia.org/wiki/Gamma_radiation) | 44Sc | | [ε](https://en.wikipedia.org/wiki/Electron_capture) | [44Ca](https://en.wikipedia.org/wiki/Calcium-44) | | **45Sc** | 100% | [stable](https://en.wikipedia.org/wiki/Stable_isotope) | | | | **46Sc** | syn | 83.79 d | [β−](https://en.wikipedia.org/wiki/Beta_emission) | [46Ti](https://en.wikipedia.org/wiki/Titanium-46) | | γ | – | | **47Sc** | syn | 80.38 d | β− | [47Ti](https://en.wikipedia.org/wiki/Titanium-47) | | γ | – | | **48Sc** | syn | 43.67 h | β− | [48Ti](https://en.wikipedia.org/wiki/Titanium-48) | | γ | – | | |
| * [view](https://en.wikipedia.org/wiki/Template:Infobox_scandium) * [talk](https://en.wikipedia.org/wiki/Template_talk:Infobox_scandium) * [edit](https://en.wikipedia.org/w/index.php?title=Template:Infobox_scandium&action=edit)   | [references](https://en.wikipedia.org/wiki/List_of_data_references_for_chemical_elements) | |

**Scandium** is a [chemical element](https://en.wikipedia.org/wiki/Chemical_element) with symbol **Sc** and [atomic number](https://en.wikipedia.org/wiki/Atomic_number) 21. A silvery-white metallic [d-block element](https://en.wikipedia.org/wiki/D-block), it has historically been classified as a [rare-earth element](https://en.wikipedia.org/wiki/Rare-earth_element),[[5]](https://en.wikipedia.org/wiki/Scandium#cite_note-5) together with [yttrium](https://en.wikipedia.org/wiki/Yttrium) and the [lanthanides](https://en.wikipedia.org/wiki/Lanthanide). It was discovered in 1879 by spectral analysis of the [minerals](https://en.wikipedia.org/wiki/Mineral) [euxenite](https://en.wikipedia.org/wiki/Euxenite) and [gadolinite](https://en.wikipedia.org/wiki/Gadolinite) from [Scandinavia](https://en.wikipedia.org/wiki/Scandinavia).

Scandium is present in most of the deposits of rare-earth and [uranium](https://en.wikipedia.org/wiki/Uranium) compounds, but it is extracted from these ores in only a few mines worldwide. Because of the low availability and the difficulties in the preparation of metallic scandium, which was first done in 1937, applications for scandium were not developed until the 1970s. The positive effects of scandium on [aluminium alloys](https://en.wikipedia.org/wiki/Aluminium_alloy) were discovered in the 1970s, and its use in such alloys remains its only major application. The global trade of scandium oxide is about 10 [tonnes](https://en.wikipedia.org/wiki/Tonne) per year.

The properties of scandium compounds are intermediate between those of [aluminium](https://en.wikipedia.org/wiki/Aluminium) and [yttrium](https://en.wikipedia.org/wiki/Yttrium). A [diagonal relationship](https://en.wikipedia.org/wiki/Diagonal_relationship) exists between the behavior of [magnesium](https://en.wikipedia.org/wiki/Magnesium) and scandium, just as there is between [beryllium](https://en.wikipedia.org/wiki/Beryllium) and aluminium. In the chemical compounds of the elements in group 3, the predominant [oxidation state](https://en.wikipedia.org/wiki/Oxidation_state) is +3.



**Contents**

* [1 Properties](https://en.wikipedia.org/wiki/Scandium#Properties)
  + [1.1 Chemical characteristics](https://en.wikipedia.org/wiki/Scandium#Chemical_characteristics)
  + [1.2 Isotopes](https://en.wikipedia.org/wiki/Scandium#Isotopes)
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**Properties**

**Chemical characteristics**

Scandium is a soft metal with a silvery appearance. It develops a slightly yellowish or pinkish cast when [oxidized](https://en.wikipedia.org/wiki/Redox) by air. It is susceptible to weathering and dissolves slowly in most dilute [acids](https://en.wikipedia.org/wiki/Acids). It does not react with a 1:1 mixture of [nitric acid](https://en.wikipedia.org/wiki/Nitric_acid) (HNO3) and 48% [hydrofluoric acid](https://en.wikipedia.org/wiki/Hydrofluoric_acid) (HF), possibly due to the formation of an impermeable [passive layer](https://en.wikipedia.org/wiki/Passivation_(chemistry)). Scandium turnings ignite in air with a brilliant yellow flame to form [scandium oxide](https://en.wikipedia.org/wiki/Scandium_oxide).[[6]](https://en.wikipedia.org/wiki/Scandium#cite_note-6)

**Isotopes**

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

In nature, scandium is found exclusively as the [isotope](https://en.wikipedia.org/wiki/Isotope) 45Sc, which has a [nuclear spin](https://en.wikipedia.org/wiki/Nuclear_spin) of 7/2; this is its only stable isotope. Thirteen [radioisotopes](https://en.wikipedia.org/wiki/Radioisotope) have been characterized with the most stable being 46Sc, which has a [half-life](https://en.wikipedia.org/wiki/Half-life) of 83.8 days; 47Sc, 3.35 days; the [positron](https://en.wikipedia.org/wiki/Positron) emitter [44Sc](https://en.wikipedia.org/wiki/Scandium-44), 4 h; and 48Sc, 43.7 hours. All of the remaining [radioactive](https://en.wikipedia.org/wiki/Radioactivity) isotopes have half-lives less than 4 hours, and the majority of these have half-lives less than 2 minutes. This element also has five [nuclear isomers](https://en.wikipedia.org/wiki/Nuclear_isomer), with the most stable being 44mSc (*t*1/2 = 58.6 h).[[7]](https://en.wikipedia.org/wiki/Scandium#cite_note-Audi-7)

The isotopes of scandium range from 36Sc to 60Sc. The primary [decay mode](https://en.wikipedia.org/wiki/Decay_mode) at masses lower than the only stable isotope, 45Sc, is [electron capture](https://en.wikipedia.org/wiki/Electron_capture), and the primary mode at masses above it is [beta emission](https://en.wikipedia.org/wiki/Beta_emission). The primary [decay products](https://en.wikipedia.org/wiki/Decay_product) at atomic weights below 45Sc are [calcium](https://en.wikipedia.org/wiki/Calcium) isotopes and the primary products from higher atomic weights are [titanium](https://en.wikipedia.org/wiki/Titanium) isotopes.[[7]](https://en.wikipedia.org/wiki/Scandium#cite_note-Audi-7)

**Occurrence**

In [Earth's crust](https://en.wikipedia.org/wiki/Abundance_of_elements_in_Earth%27s_crust), scandium is not rare. Estimates vary from 18 to 25 ppm, which is comparable to the abundance of [cobalt](https://en.wikipedia.org/wiki/Cobalt) (20–30 ppm). Scandium is only the 50th most common element on Earth (35th most abundant in the crust), but it is the 23rd most common element in the [Sun](https://en.wikipedia.org/wiki/Sun).[[8]](https://en.wikipedia.org/wiki/Scandium#cite_note-rubber-8) However, scandium is distributed sparsely and occurs in trace amounts in many [minerals](https://en.wikipedia.org/wiki/Mineral).[[9]](https://en.wikipedia.org/wiki/Scandium#cite_note-9) Rare minerals from Scandinavia[[10]](https://en.wikipedia.org/wiki/Scandium#cite_note-Thort-10) and [Madagascar](https://en.wikipedia.org/wiki/Madagascar)[[11]](https://en.wikipedia.org/wiki/Scandium#cite_note-Mada-11) such as [thortveitite](https://en.wikipedia.org/wiki/Thortveitite), [euxenite](https://en.wikipedia.org/wiki/Euxenite), and [gadolinite](https://en.wikipedia.org/wiki/Gadolinite) are the only known concentrated sources of this element. Thortveitite can contain up to 45% of scandium in the form of [scandium oxide](https://en.wikipedia.org/wiki/Scandium_oxide).[[10]](https://en.wikipedia.org/wiki/Scandium#cite_note-Thort-10)

The stable form of scandium is created in [supernovas](https://en.wikipedia.org/wiki/Supernova) via the [r-process](https://en.wikipedia.org/wiki/R-process).[[12]](https://en.wikipedia.org/wiki/Scandium#cite_note-12)

**Production**

The world production of scandium is in the order of 15 tonnes per year, in the form of [scandium oxide](https://en.wikipedia.org/wiki/Scandium_oxide). The demand is about 50% higher, and both the production and demand keep increasing. In 2003, only three mines produced scandium: the uranium and [iron](https://en.wikipedia.org/wiki/Iron) mines in [Zhovti Vody](https://en.wikipedia.org/wiki/Zhovti_Vody) in [Ukraine](https://en.wikipedia.org/wiki/Ukraine), the rare-earth mines in [Bayan Obo](https://en.wikipedia.org/wiki/Bayan_Obo), [China](https://en.wikipedia.org/wiki/China), and the apatite mines in the [Kola peninsula](https://en.wikipedia.org/wiki/Kola_peninsula), [Russia](https://en.wikipedia.org/wiki/Russia); since then many other countries have built scandium-producing facilities, including 5 tonnes/year (7.5 tonnes/year Sc2O3) by [Nickel Asia Corporation](https://en.wikipedia.org/wiki/Nickel_Asia_Corporation) and [Sumitomo Metal Mining](https://en.wikipedia.org/wiki/Sumitomo_Metal_Mining) in the [Philippines](https://en.wikipedia.org/wiki/Philippines).[[13]](https://en.wikipedia.org/wiki/Scandium#cite_note-SMMPressRelease-13)[[14]](https://en.wikipedia.org/wiki/Scandium#cite_note-SMMAbstract-14) In each case scandium is a byproduct from the extraction of other elements and is sold as scandium oxide.[[15]](https://en.wikipedia.org/wiki/Scandium#cite_note-Deschamps-15)[[16]](https://en.wikipedia.org/wiki/Scandium#cite_note-USGS2015-16)[[17]](https://en.wikipedia.org/wiki/Scandium#cite_note-usgs-17)

To produce metallic scandium, the oxide is converted to [scandium fluoride](https://en.wikipedia.org/wiki/Scandium_fluoride) and then [reduced](https://en.wikipedia.org/wiki/Redox) with metallic [calcium](https://en.wikipedia.org/wiki/Calcium).

[Madagascar](https://en.wikipedia.org/wiki/Madagascar) and the [Iveland](https://en.wikipedia.org/wiki/Iveland)-[Evje](https://en.wikipedia.org/wiki/Evje) region in [Norway](https://en.wikipedia.org/wiki/Norway) have the only deposits of minerals with high scandium content, [thortveitite](https://en.wikipedia.org/wiki/Thortveitite) (Sc,Y)2(Si2O7) and [kolbeckite](https://en.wikipedia.org/wiki/Kolbeckite) ScPO4·2H2O, but these are not being exploited.[[16]](https://en.wikipedia.org/wiki/Scandium#cite_note-USGS2015-16)

The absence of reliable, secure, stable, long-term production has limited the commercial applications of scandium. Despite this low level of use, scandium offers significant benefits. Particularly promising is the strengthening of aluminium alloys with as little as 0.5% scandium. Scandium-stabilized zirconia enjoys a growing market demand for use as a high-efficiency [electrolyte](https://en.wikipedia.org/wiki/Electrolyte) in [solid oxide fuel cells](https://en.wikipedia.org/wiki/Solid_oxide_fuel_cell).

**Price**

Because of its rarity, scandium is among the most expensive elements. Price for pure scandium fluctuates between 4,000 and 20,000 US dollars per kilogram. Meanwhile, the limited market generates a variety of prices at any given time. In 2010, at the peak of the rare-earths shortage, the price of scandium rose to over 15,000 US dollars per kilogram, and the widely commercially used scandium oxide (Sc2O3) was selling above 7 000 US dollars per kilogram. Since then the limited demand coupled with steady production keeps the price at its 20-year average.[[18]](https://en.wikipedia.org/wiki/Scandium#cite_note-18)

**Compounds**

See also: the categories [Scandium compounds](https://en.wikipedia.org/wiki/Category:Scandium_compounds) and [Scandium minerals](https://en.wikipedia.org/wiki/Category:Scandium_minerals).

Scandium chemistry is almost completely dominated by the trivalent ion, Sc3+. The radii of M3+ ions in the table below indicate that the chemical properties of scandium ions have more in common with yttrium ions than with aluminium ions. In part because of this similarity, scandium is often classified as a lanthanide-like element.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Ionic radii (pm) | | | | |
| [Al](https://en.wikipedia.org/wiki/Aluminium) | Sc | [Y](https://en.wikipedia.org/wiki/Yttrium) | [La](https://en.wikipedia.org/wiki/Lanthanum) | [Lu](https://en.wikipedia.org/wiki/Lutetium) |
| 53.5 | 74.5 | 90.0 | 103.2 | 86.1 |

**Oxides and hydroxides**

The oxide [Sc  
2O  
3](https://en.wikipedia.org/wiki/Scandium_oxide) and the hydroxide Sc(OH)  
3 are [amphoteric](https://en.wikipedia.org/wiki/Amphoteric):[[19]](https://en.wikipedia.org/wiki/Scandium#cite_note-19)

Sc(OH)  
3 + 3 OH−  
→ [Sc(OH)  
6]3−  
(scandate ion)

Sc(OH)  
3 + 3 H+  
+ 3 H  
2O → [Sc(H  
2O)  
6]3+

α- and γ-ScOOH are isostructural with their [aluminium hydroxide oxide](https://en.wikipedia.org/wiki/Aluminium_hydroxide_oxide) counterparts.[[20]](https://en.wikipedia.org/wiki/Scandium#cite_note-20) Solutions of Sc3+  
in water are acidic due to [hydrolysis](https://en.wikipedia.org/wiki/Hydrolysis).

**Halides and pseudohalides**

The [halides](https://en.wikipedia.org/wiki/Halide) ScX3, where X= [Cl](https://en.wikipedia.org/wiki/Scandium_chloride), [Br](https://en.wikipedia.org/wiki/Scandium_bromide), or [I](https://en.wikipedia.org/wiki/Scandium_triiodide), are very soluble in water, but [ScF3](https://en.wikipedia.org/wiki/Scandium_fluoride) is insoluble. In all four halides, the scandium is 6-coordinated. The halides are [Lewis acids](https://en.wikipedia.org/wiki/Lewis_acids); for example, [ScF3](https://en.wikipedia.org/wiki/Scandium_fluoride) dissolves in a solution containing excess fluoride ion to form [ScF6]3−. The coordination number 6 is typical for Sc(III). In the larger Y3+ and La3+ ions, [coordination numbers](https://en.wikipedia.org/wiki/Coordination_number) of 8 and 9 are common. [Scandium triflate](https://en.wikipedia.org/wiki/Scandium_triflate) is sometimes used as a [Lewis acid](https://en.wikipedia.org/wiki/Lewis_acid) catalyst in [organic chemistry](https://en.wikipedia.org/wiki/Organic_chemistry).

**Organic derivatives**

Main article: [Organoscandium chemistry](https://en.wikipedia.org/wiki/Organoscandium_chemistry)

Scandium forms a series of organometallic compounds with [cyclopentadienyl](https://en.wikipedia.org/wiki/Cyclopentadienyl_complex) ligands (Cp), similar to the behavior of the lanthanides. One example is the chlorine-bridged dimer, [ScCp2Cl]2 and related derivatives of [pentamethylcyclopentadienyl](https://en.wikipedia.org/wiki/Pentamethylcyclopentadienyl) ligands.[[21]](https://en.wikipedia.org/wiki/Scandium#cite_note-21)

**Uncommon oxidation states**

Compounds that feature scandium in the oxidation state other than +3 are rare but well characterized. The blue-black compound CsScCl3 is one of the simplest. This material adopts a sheet-like structure that exhibits extensive bonding between the scandium(II) centers.[[22]](https://en.wikipedia.org/wiki/Scandium#cite_note-22) [Scandium hydride](https://en.wikipedia.org/wiki/Scandium_hydride) is not well understood, although it appears not to be a [saline hydride](https://en.wikipedia.org/wiki/Hydride) of Sc(II).[[3]](https://en.wikipedia.org/wiki/Scandium#cite_note-McGuire-3) As is observed for most elements, a diatomic scandium hydride has been observed spectroscopically at high temperatures in the gas phase.[[2]](https://en.wikipedia.org/wiki/Scandium#cite_note-Smith-2) Scandium borides and carbides are [non-stoichiometric](https://en.wikipedia.org/wiki/Non-stoichiometric_compound), as is typical for neighboring elements.[[23]](https://en.wikipedia.org/wiki/Scandium#cite_note-Holleman-23)

Lower oxidation states (+2, +1, 0) have also been observed in organoscandium compounds.[[24]](https://en.wikipedia.org/wiki/Scandium#cite_note-24)[[25]](https://en.wikipedia.org/wiki/Scandium#cite_note-25)[[26]](https://en.wikipedia.org/wiki/Scandium#cite_note-26)[[27]](https://en.wikipedia.org/wiki/Scandium#cite_note-27)

**History**

[Dmitri Mendeleev](https://en.wikipedia.org/wiki/Dmitri_Mendeleev), who is referred to as the father of the [periodic table](https://en.wikipedia.org/wiki/Periodic_table), predicted the existence of an element [*ekaboron*](https://en.wikipedia.org/wiki/Mendeleev%27s_predicted_elements#Ekaboron_and_scandium), with an [atomic mass](https://en.wikipedia.org/wiki/Atomic_mass) between 40 and 48 in 1869. [Lars Fredrik Nilson](https://en.wikipedia.org/wiki/Lars_Fredrik_Nilson) and his team [detected this element](https://en.wikipedia.org/wiki/Discovery_of_the_chemical_elements) in the minerals [euxenite](https://en.wikipedia.org/wiki/Euxenite) and [gadolinite](https://en.wikipedia.org/wiki/Gadolinite) in 1879. Nilson prepared 2 grams of [scandium oxide](https://en.wikipedia.org/wiki/Scandium_oxide) of high purity.[[28]](https://en.wikipedia.org/wiki/Scandium#cite_note-Nilsonfr-28)[[29]](https://en.wikipedia.org/wiki/Scandium#cite_note-Nilsonde-29) He named the element scandium, from the [Latin](https://en.wikipedia.org/wiki/Latin) *Scandia* meaning "Scandinavia". Nilson was apparently unaware of Mendeleev's prediction, but [Per Teodor Cleve](https://en.wikipedia.org/wiki/Per_Teodor_Cleve) recognized the correspondence and notified Mendeleev.[[30]](https://en.wikipedia.org/wiki/Scandium#cite_note-30)

Metallic scandium was produced for the first time in 1937 by [electrolysis](https://en.wikipedia.org/wiki/Electrolysis) of a [eutectic](https://en.wikipedia.org/wiki/Eutectic) mixture of [potassium](https://en.wikipedia.org/wiki/Potassium), [lithium](https://en.wikipedia.org/wiki/Lithium), and [scandium chlorides](https://en.wikipedia.org/wiki/Scandium_chloride), at 700–800 °[C](https://en.wikipedia.org/wiki/Celsius).[[31]](https://en.wikipedia.org/wiki/Scandium#cite_note-31) The first pound of 99% pure scandium metal was produced in 1960. Production of aluminium alloys began in 1971, following a US patent.[[32]](https://en.wikipedia.org/wiki/Scandium#cite_note-32) Aluminium-scandium alloys were also developed in the [USSR](https://en.wikipedia.org/wiki/USSR).[[33]](https://en.wikipedia.org/wiki/Scandium#cite_note-Zark-33)

Laser crystals of gadolinium-scandium-gallium garnet (GSGG) were used in strategic defense applications developed for the [Strategic Defense Initiative](https://en.wikipedia.org/wiki/Strategic_Defense_Initiative) (SDI) in the 1980s and 1990s.[[34]](https://en.wikipedia.org/wiki/Scandium#cite_note-34)[[35]](https://en.wikipedia.org/wiki/Scandium#cite_note-35)

**Red giant stars near the** [**Galactic Center**](https://en.wikipedia.org/wiki/Galactic_Center)

In early 2018, evidence was gathered from [spectrometer](https://en.wikipedia.org/wiki/Spectrometer) data of significant scandium, [vanadium](https://en.wikipedia.org/wiki/Vanadium) and [yttrium](https://en.wikipedia.org/wiki/Yttrium) abundances in [red giant](https://en.wikipedia.org/wiki/Red_giant) stars in the [Nuclear Star Cluster](https://en.wikipedia.org/w/index.php?title=Nuclear_Star_Cluster&action=edit&redlink=1) (NSC) in the [Galactic Center](https://en.wikipedia.org/wiki/Galactic_Center). Further research showed that this was an illusion caused by the relatively low temperature (below 3,500 K) of these stars masking the abundance signals, and that this phenomenon was observable in other red giants.[[36]](https://en.wikipedia.org/wiki/Scandium#cite_note-””-36)

**Applications**

[](https://en.wikipedia.org/wiki/File:Mig-29_on_landing.jpg)

Parts of the [MiG-29](https://en.wikipedia.org/wiki/Mikoyan-Gurevich_MiG-29) are made from Al-Sc alloy.[[37]](https://en.wikipedia.org/wiki/Scandium#cite_note-Ahmad2003-37)

The addition of scandium to aluminium limits the grain growth in the heat zone of welded aluminium components. This has two beneficial effects: the precipitated Al3Sc forms smaller crystals than in other [aluminium alloys](https://en.wikipedia.org/wiki/Aluminium_alloy),[[37]](https://en.wikipedia.org/wiki/Scandium#cite_note-Ahmad2003-37) and the volume of precipitate-free zones at the grain boundaries of age-hardening aluminium alloys is reduced.[[37]](https://en.wikipedia.org/wiki/Scandium#cite_note-Ahmad2003-37) Both of these effects increase the usefulness of the alloy.[[*why?*](https://en.wikipedia.org/wiki/Wikipedia:Please_clarify)] However, [titanium alloys](https://en.wikipedia.org/wiki/Titanium_alloy), which are similar in lightness and strength, are cheaper and much more widely used.[[38]](https://en.wikipedia.org/wiki/Scandium#cite_note-Schwarz2004-38)

The alloy Al20Li20Mg10Sc20Ti30 is as strong as titanium, light as aluminium, and hard as ceramic.[[39]](https://en.wikipedia.org/wiki/Scandium#cite_note-39)

The main application of scandium by weight is in aluminium-scandium alloys for minor aerospace industry components. These alloys contain between 0.1% and 0.5% of scandium. They were used in the Russian military aircraft, specifically the [MiG-21](https://en.wikipedia.org/wiki/Mikoyan-Gurevich_MiG-21) and [MiG-29](https://en.wikipedia.org/wiki/Mikoyan_MiG-29).[[37]](https://en.wikipedia.org/wiki/Scandium#cite_note-Ahmad2003-37)

Some items of sports equipment, which rely on high-performance materials, have been made with scandium-aluminium alloys, including [baseball bats](https://en.wikipedia.org/wiki/Baseball_bat)[[40]](https://en.wikipedia.org/wiki/Scandium#cite_note-bat-40) and [bicycle frames](https://en.wikipedia.org/wiki/Bicycle_frame) and [components](https://en.wikipedia.org/wiki/List_of_bicycle_parts).[[41]](https://en.wikipedia.org/wiki/Scandium#cite_note-41) [Lacrosse sticks](https://en.wikipedia.org/wiki/Lacrosse_sticks) are also made with scandium. The American firearm manufacturing company [Smith & Wesson](https://en.wikipedia.org/wiki/Smith_%26_Wesson) produces semi-automatic pistols and revolvers with frames of scandium alloy and cylinders of titanium or carbon steel.[[42]](https://en.wikipedia.org/wiki/Scandium#cite_note-James2004-42)[[43]](https://en.wikipedia.org/wiki/Scandium#cite_note-Sweeney2004-43)

Dentists use erbium-chromium-doped yttrium-scandium-gallium garnet (Er,Cr:YSGG) lasers for cavity preparation and in endodontics.[[44]](https://en.wikipedia.org/wiki/Scandium#cite_note-44)

The first scandium-based metal-halide lamps were patented by [General Electric](https://en.wikipedia.org/wiki/General_Electric) and initially made in North America, although they are now produced in all major industrialized countries. Approximately 20 kg of scandium (as Sc2[O](https://en.wikipedia.org/wiki/Oxygen)3) is used annually in the [United States](https://en.wikipedia.org/wiki/United_States) for high-intensity discharge lamps.[[45]](https://en.wikipedia.org/wiki/Scandium#cite_note-CRC-45) One type of [metal-halide lamp](https://en.wikipedia.org/wiki/Metal-halide_lamp), similar to the [mercury-vapor lamp](https://en.wikipedia.org/wiki/Mercury-vapor_lamp), is made from [scandium triiodide](https://en.wikipedia.org/wiki/Scandium_triiodide) and [sodium iodide](https://en.wikipedia.org/wiki/Sodium_iodide). This lamp is a white-light source with high [color rendering index](https://en.wikipedia.org/wiki/Color_rendering_index) that sufficiently resembles sunlight to allow good color-reproduction with [TV](https://en.wikipedia.org/wiki/Television) cameras.[[46]](https://en.wikipedia.org/wiki/Scandium#cite_note-46) About 80 kg of scandium is used in metal-halide lamps/light bulbs globally per year.[[*citation needed*](https://en.wikipedia.org/wiki/Wikipedia:Citation_needed)]

The [radioactive isotope](https://en.wikipedia.org/wiki/Radioactive_isotope) 46Sc is used in [oil refineries](https://en.wikipedia.org/wiki/Oil_refinery) as a tracing agent.[[45]](https://en.wikipedia.org/wiki/Scandium#cite_note-CRC-45) [Scandium triflate](https://en.wikipedia.org/wiki/Scandium_triflate) is a catalytic [Lewis acid](https://en.wikipedia.org/wiki/Lewis_acid) used in [organic chemistry](https://en.wikipedia.org/wiki/Organic_chemistry).[[47]](https://en.wikipedia.org/wiki/Scandium#cite_note-47)

**Health and safety**

Elemental scandium is considered non-toxic, though extensive animal testing of scandium compounds has not been done.[[48]](https://en.wikipedia.org/wiki/Scandium#cite_note-48) The [median lethal dose](https://en.wikipedia.org/wiki/Median_lethal_dose) (LD50) levels for [scandium chloride](https://en.wikipedia.org/wiki/Scandium_chloride) for rats have been determined as 4 mg/kg for [intraperitoneal](https://en.wikipedia.org/wiki/Intraperitoneal_injection) and 755 mg/kg for oral administration.[[49]](https://en.wikipedia.org/wiki/Scandium#cite_note-49) In the light of these results, compounds of scandium should be handled as compounds of moderate toxicity.

**See also**

* [Rare-earth element](https://en.wikipedia.org/wiki/Rare-earth_element)

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