

= Scandium =

Scandium is a chemical element with symbol Sc and atomic number 21 . A silvery @-@ white metallic d @-@ block element , it has historically been sometimes classified as a rare earth element , together with yttrium and the lanthanoids . It was discovered in 1879 by spectral analysis of the minerals euxenite and gadolinite from Scandinavia .

Scandium is present in most of the deposits of rare earth and 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 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 per year .

The properties of scandium compounds are intermediate between those of aluminium and yttrium . A diagonal relationship exists between the behavior of magnesium and scandium , just as there is between beryllium and aluminium . In the chemical compounds of the elements in group 3 , the predominant oxidation state is + 3 .

= = Properties = =

= = = Chemical characteristics of the element = = =

Scandium is a soft metal with a silvery appearance . It develops a slightly yellowish or pinkish cast when oxidized by air . It is susceptible to weathering and dissolves slowly in most dilute acids . It does not react with a 1 : 1 mixture of nitric acid (HNO_3) and 48 % hydrofluoric acid (HF) , possibly due to the formation of an impermeable passive layer . Scandium turnings ignite in air with a brilliant yellow flame to form scandium (III) oxide .

= = = Isotopes = = =

In nature , scandium is found exclusively as the isotope ^{45}Sc , which has a nuclear spin of $7/2$. Thirteen radioisotopes have been characterized with the most stable being ^{46}Sc , which has a half @-@ life of 83 @-@ 8 days ; ^{47}Sc , 3 @-@ 35 days ; the positron emitter ^{44}Sc , 4 h ; and ^{48}Sc , 43 @-@ 7 hours . All of the remaining radioactive 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 meta states , with the most stable being $^{44\text{m}}\text{Sc}$ ($t_{1/2} = 58$ @-@ 6 h) .

The isotopes of scandium range from ^{36}Sc to ^{60}Sc . The primary decay mode at masses lower than the only stable isotope , ^{45}Sc , is electron capture , and the primary mode at masses above it is beta emission . The primary decay products at atomic weights below ^{45}Sc are calcium isotopes and the primary products from higher atomic weights are titanium isotopes .

= = = Occurrence = = =

In Earth 's crust , scandium is not rare . Estimates vary from 18 to 25 ppm , which is comparable to the abundance of 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 . However , scandium is distributed sparsely and occurs in trace amounts in many minerals . Rare minerals from Scandinavia and Madagascar such as thortveitite , euxenite , and gadolinite are the only known concentrated sources of this element . Thortveitite can contain up to 45 % of scandium in the form of scandium (III) oxide .

The stable form of scandium is created in supernovas via the r @-@ process .

= = Production = =

The world production of scandium is in the order of 10 tonnes per year, in the form of 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 mines in Zhovti Vody in Ukraine, the rare earth mines in Bayan Obo, China, and the apatite mines in the Kola peninsula, Russia; since then many other countries have built scandium @-@ producing facilities. In each case scandium is a byproduct from the extraction of other elements and is sold as scandium oxide.

To produce metallic scandium, the oxide is converted to scandium fluoride and reduced with metallic calcium.

Madagascar and Iveland @-@ Evje region in Norway have the only deposits of minerals with high scandium content, thortveitite (Sc, Y)₂(Si₂O₇) and kolbeckite ScPO₄ · 2H₂O, but these are not being exploited.

The absence of reliable, secure, stable, and long term production has limited 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 in solid oxide fuel cells.

= = Compounds = =

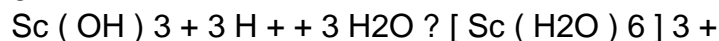
Scandium chemistry is almost completely dominated by the trivalent ion, Sc³⁺. The radii of M³⁺ ions in the table below indicate that the chemical properties of scandium ions have more in common with yttrium ions than with aluminium ions. In part because of this similarity, scandium is often classified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

= = Oxides and hydroxides = =

The oxide Sc₂O₃ and the hydroxide Sc(OH)₃ are amphoteric:



6



The ³⁻ and ³⁺ forms of scandium oxide hydroxide (ScO(OH)), are isostructural with their aluminium oxide hydroxide counterparts. Solutions of Sc³⁺ in water are acidic because of hydrolysis.

= = Halides and pseudohalides = =

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

= = Organic derivatives = =

Scandium forms a series of organometallic compounds with cyclopentadienyl ligands (Cp), similar to the behavior of the lanthanides. One example is the chlorine @-@ bridged dimer, [ScCp₂Cl]₂ and related derivatives of pentamethylcyclopentadienyl ligands.

= = 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 . Scandium hydride is not well understood , although it appears not to be a saline hydride of Sc (II) . As is observed for most elements , a diatomic scandium hydride has been observed spectroscopically at high temperatures in the gas phase . Scandium borides and carbides are non @-@ stoichiometric , as is typical for neighboring elements .

Lower oxidation states (+ 2 , + 1 , 0) have also been observed in organoscandium compounds .

= = History = =

Dmitri Mendeleev , who is referred to as the father of the periodic table , predicted the existence of an element ekaboron , with an atomic mass between 40 and 48 in 1869 . Lars Fredrik Nilson and his team detected this element in the minerals euxenite and gadolinite . Nilson prepared 2 grams of scandium oxide of high purity . He named the element scandium , from the Latin Scandia meaning " Scandinavia " . Nilson was apparently unaware of Mendeleev 's prediction , but Per Teodor Cleve recognized the correspondence and notified Mendeleev .

Metallic scandium was produced for the first time in 1937 by electrolysis of a eutectic mixture of potassium , lithium , and scandium chlorides , at 700 ? 800 ° C. The first pound of 99 % pure scandium metal was produced in 1960 . Production of aluminium alloys began in 1971 , following a US patent . Aluminium @-@ scandium alloys were also developed in the USSR .

Laser crystals of gadolinium @-@ scandium @-@ gallium garnet (GSGG) were used in strategic defense applications developed for the Strategic Defense Initiative (SDI) in the 1980s and 1990s .

= = Applications = =

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 , and the volume of precipitate @-@ free zones at the grain boundaries of age @-@ hardening aluminium alloys is reduced . Both of these effects increase the usefulness of the alloy . However , titanium alloys , which are similar in lightness and strength , are cheaper and much more widely used .

The alloy Al20Li20Mg10Sc20Ti30 is as strong as titanium , light as aluminium , and hard as ceramic .

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 and MiG @-@ 29 .

Some items of sports equipment , which rely on high performance materials , have been made with scandium @-@ aluminium alloys , including baseball bats and bicycle frames and components . Lacrosse sticks are also made with scandium . The American firearm manufacturing company , Smith & Wesson , produces revolvers with frames of scandium alloy and cylinders of titanium or carbon steel .

Dentists use erbium , chromium : yttrium @-@ scandium @-@ gallium garnet (Er , Cr : YSGG) lasers for cavity preparation and in endodontics .

The first scandium @-@ based metal halide lamps were patented by General Electric and initially made in North America , although they are now produced in all major industrialized countries . Approximately 20 kg (as Sc2O3) of scandium is used annually in the United States for high @-@ intensity discharge lamps . One type of metal halide lamp , similar to the mercury @-@ vapor lamp , is made from Scandium iodide and sodium iodide . This lamp is a white light source with high color rendering index that sufficiently resembles sunlight to allow good color @-@ reproduction with TV cameras . About 80 kg of scandium is used in metal halide lamps / light bulbs globally per year .

The radioactive isotope 46Sc is used in oil refineries as a tracing agent . Scandium triflate is a catalytic Lewis acid used in organic chemistry .

= = Health and safety = =

Elemental scandium is considered non @-@ toxic , though extensive animal testing of scandium compounds has not been done . The median lethal dose (LD50) levels for scandium (III) chloride for rats have been determined as 4 mg / kg for intraperitoneal and 755 mg / kg for oral administration . In the light of these results compounds of scandium should be handled as compounds of moderate toxicity .