= Dysprosium =

Dysprosium is a chemical element with the symbol Dy and atomic number 66 . It is a rare earth element with a metallic silver luster . Dysprosium is never found in nature as a free element , though it is found in various minerals , such as xenotime . Naturally occurring dysprosium is composed of seven isotopes , the most abundant of which is 164Dy .

Dysprosium was first identified in 1886 by Paul Émile Lecoq de Boisbaudran , but was not isolated in pure form until the development of ion exchange techniques in the 1950s . Dysprosium is used for its high thermal neutron absorption cross @-@ section in making control rods in nuclear reactors , for its high magnetic susceptibility in data storage applications , and as a component of Terfenol @-@ D (a magnetostrictive material) . Soluble dysprosium salts are mildly toxic , while the insoluble salts are considered non @-@ toxic .

= = Characteristics = =

= = = Physical properties = = =

Dysprosium is a rare earth element that has a metallic , bright silver luster . It is soft enough to be cut with a knife , and can be machined without sparking if overheating is avoided . Dysprosium 's physical characteristics can be greatly affected by even small amounts of impurities .

Dysprosium and holmium have the highest magnetic strengths of the elements , especially at low temperatures . Dysprosium has a simple ferromagnetic ordering at temperatures below 85 K (? 188 @.@ 2 ° C) . Above 85 K (? 188 @.@ 2 ° C) , it turns into an helical antiferromagnetic state in which all of the atomic moments in a particular basal plane layer are parallel , and oriented at a fixed angle to the moments of adjacent layers . This unusual antiferromagnetism transforms into a disordered (paramagnetic) state at 179 K (? 94 ° C) .

= = = Chemical properties = = =

Dysprosium metal tarnishes slowly in air and burns readily to form dysprosium (III) oxide :

4 Dy + 3 O2 ? 2 Dy2O3

Dysprosium is quite electropositive and reacts slowly with cold water (and quite quickly with hot water) to form dysprosium hydroxide :

2 Dy (s) + 6 H2O (l) ? 2 Dy (OH) 3 (aq) + 3 H2 (g)

Dysprosium metal vigorously reacts with all the halogens at above 200 ° C :

2 Dy (s) + 3 F2 (g) ? 2 DyF3 (s) [green]

2 Dy (s) + 3 Cl2 (g) ? 2 DyCl3 (s) [white]

2 Dy (s) + 3 Br2 (g) ? 2 DyBr3 (s) [white]

2 Dy (s) + 3 I2 (g) ? 2 DyI3 (s) [green]

Dysprosium dissolves readily in dilute sulfuric acid to form solutions containing the yellow Dy (III) ions , which exist as a [Dy (OH2) 9] 3 + complex :

2 Dy (s) + 3 H2SO4 (aq) ? 2 Dy3 + (aq) + 3 SO2 ?

4 (aq) + 3 H2 (g)

The resulting compound , dysprosium (III) sulfate , is noticeably paramagnetic .

= = = Compounds = = =

Dysprosium halides , such as DyF3 and DyBr3 , tend to take on a yellow color . Dysprosium oxide , also known as dysprosia , is a white powder that is highly magnetic , more so than iron oxide .

Dysprosium combines with various non @-@ metals at high temperatures to form binary compounds with varying composition and oxidation states + 3 and sometimes + 2 , such as DyN , DyP , DyH2 and DyH3 ; DyS , DyS2 , Dy2S3 and Dy5S7 ; DyB2 , DyB4 , DyB6 and DyB12 , as well

as Dy3C and Dy2C3 .

Dysprosium carbonate , Dy2 (CO3) 3 , and dysprosium sulfate , Dy2 (SO4) 3 , result from similar reactions . Most dysprosium compounds are soluble in water , though dysprosium carbonate tetrahydrate (Dy2 (CO3) 3 · 4H2O) and dysprosium oxalate decahydrate (Dy2 (C2O4) 3 · 10H2O) are both insoluble in water . Two of the most abundant dysprosium carbonates , tengerite- (Dy) (Dy2 (CO3) 3 · 2 ? 3H2O) and kozoite- (Dy) (DyCO3 (OH)) are known to form via a poorly ordered (amorphous) precursor phase with a formula of Dy2 (CO3) 3 · 4H2O . This amorphous precursor consists of highly hydrated spherical nanoparticles of 10 ? 20 nm diameter that are exceptionally stable under dry treatment at ambient and high temperatures .

= = = Isotopes = = =

Naturally occurring dysprosium is composed of seven isotopes : 156Dy , 158Dy , 160Dy , 161Dy , 162Dy , 163Dy , and 164Dy . These are all considered stable , although 156Dy decays by alpha decay with a half @-@ life of over 1 × 1018 years . Of the naturally occurring isotopes , 164Dy is the most abundant at 28 % , followed by 162Dy at 26 % . The least abundant is 156Dy at 0 @.@ 06 % .

Twenty @-@ nine radioisotopes have also been synthesized , ranging in atomic mass from 138 to 173 . The most stable of these is 154Dy , with a half @-@ life of approximately 3 × 106 years , followed by 159Dym with a half @-@ life of 144 @.@ 4 days . The least stable is 138Dy , with a half @-@ life of 200 ms . As a general rule , isotopes that are lighter than the stable isotopes tend to decay primarily by ? + decay , while those that are heavier tend to decay by ? ? decay . However , 154Dy decays primarily by alpha decay , and 152Dy and 159Dy decay primarily by electron capture . Dysprosium also has at least 11 metastable isomers , ranging in atomic mass from 140 to 165 . The most stable of these is 165mDy , which has a half @-@ life of 1 @.@ 257 minutes . 149Dy has two metastable isomers , the second of which , 149m2Dy , has a half @-@ life of 28 ns .

= = History = =

In 1878 , erbium ores were found to contain the oxides of holmium and thulium . French chemist Paul Émile Lecoq de Boisbaudran , while working with holmium oxide , separated dysprosium oxide from it in Paris in 1886 . His procedure for isolating the dysprosium involved dissolving dysprosium oxide in acid , then adding ammonia to precipitate the hydroxide . He was only able to isolate dysprosium from its oxide after more than 30 attempts at his procedure . On succeeding , he named the element dysprosium from the Greek dysprositos (???????????) , meaning " hard to get " . The element was not isolated in relatively pure form until after the development of ion exchange techniques by Frank Spedding at Iowa State University in the early 1950s .

In 1950 , Glenn T. Seaborg , Albert Ghiorso , and Stanley G. Thompson bombarded 241Am with helium ions , which produced atoms with an atomic number of 97 and which closely resembled the neighboring lanthanide terbium . Because terbium was named after Ytterby , the city in which it and several other elements were discovered , this new element was named berkelium for the city in which it was synthesized . However , when the research team synthesized element 98 , they could not think of a good analogy for dysprosium , and instead named the element californium in honor of the state in which it was synthesized , California . The research team went on to " point out that , in recognition of the fact that dysprosium is named on the basis of a Greek word meaning ' difficult to get at , ' that the searchers for another element a century ago found it difficult to get to California " .

= = Occurrence = =

While dysprosium is never encountered as a free element , it is found in many minerals , including xenotime , fergusonite , gadolinite , euxenite , polycrase , blomstrandine , monazite and bastnäsite ; often with erbium and holmium or other rare earth elements . Currently , most dysprosium is being obtained from the ion @-@ adsorption clay ores of southern China , and future sources will include

the Halls Creek region in Western Australia . In the high @-@ yttrium version of these , dysprosium happens to be the most abundant of the heavy lanthanides , comprising up to 7 ? 8 % of the concentrate (as compared to about 65 % for yttrium) . The concentration of Dy in the Earth 's crust is about 5 @.@ 2 mg / kg and in sea water 0 @.@ 9 ng / L.

= = Production = =

Dysprosium is obtained primarily from monazite sand , a mixture of various phosphates . The metal is obtained as a by @-@ product in the commercial extraction of yttrium . In isolating dysprosium , most of the unwanted metals can be removed magnetically or by a flotation process . Dysprosium can then be separated from other rare earth metals by an ion exchange displacement process . The resulting dysprosium ions can then react with either fluorine or chlorine to form dysprosium fluoride , DyF_3 , or dysprosium chloride , $DyCl_3$. These compounds can be reduced using either calcium or lithium metals in the following reactions :

$3\ Ca + 2\ DyF_3 \rightarrow 2\ Dy + 3\ CaF_2$

$3\ Li + DyCl_3 \rightarrow Dy + 3\ LiCl$

The components are placed in a tantalum crucible and fired in a helium atmosphere . As the reaction progresses , the resulting halide compounds and molten dysprosium separate due to differences in density . When the mixture cools , the dysprosium can be cut away from the impurities .

About 100 tonnes of dysprosium are produced worldwide each year , with 99 % of that total produced in China . Dysprosium prices have climbed nearly twentyfold , from $ 7 per pound in 2003 , to $ 130 a pound in late 2010 . The price increased to $ 1 @,@ 400 / kg in 2011 but fell to $ 240 in 2015 , largely due to illegal production in China which circumvented government restrictions .

According to the United States Department of Energy , the wide range of its current and projected uses , together with the lack of any immediately suitable replacement , makes dysprosium the single most critical element for emerging clean energy technologies - even their most conservative projections predict a shortfall of dysprosium before 2015 . As of late 2015 , there is a nascent rare earth (including dysprosium) extraction industry in Australia .

= = Applications = =

There are not many applications unique to dysprosium . Theodore Gray wrote in his book The Elements : A Visual Exploration of Every Known Atom in the Universe " Look up dysprosium , and you have to go to the fourth page of results before finding anything that isn 't a periodic table website 's entry for dysprosium , usually an obligatory ' It 's an element , so we have to have a page about it ' sort of page . "

Dysprosium is used , in conjunction with vanadium and other elements , in making laser materials and commercial lighting . Because of dysprosium 's high thermal @-@ neutron absorption cross @-@ section , dysprosium @-@ oxide ? nickel cermets are used in neutron @-@ absorbing control rods in nuclear reactors . Dysprosium ? cadmium chalcogenides are sources of infrared radiation , which is useful for studying chemical reactions . Because dysprosium and its compounds are highly susceptible to magnetization , they are employed in various data @-@ storage applications , such as in hard disks . Dysprosium is increasingly in demand for the permanent magnets used in electric car motors and wind turbine generators .

Neodymium ? iron ? boron magnets can have up to 6 % of the neodymium substituted by dysprosium to raise the coercivity for demanding applications , such as drive motors for electric vehicles and generators for wind turbines . This substitution would require up to 100 grams of dysprosium per electric car produced . Based on Toyota 's projected 2 million units per year , the use of dysprosium in applications such as this would quickly exhaust its available supply . The dysprosium substitution may also be useful in other applications , because it improves the corrosion resistance of the magnets .

Dysprosium is one of the components of Terfenol @-@ D , along with iron and terbium . Terfenol

@-@ D has the highest room @-@ temperature magnetostriction of any known material ; which is employed in transducers , wide @-@ band mechanical resonators , and high @-@ precision liquid @-@ fuel injectors .

Dysprosium is used in dosimeters for measuring ionizing radiation . Crystals of calcium sulfate or calcium fluoride are doped with dysprosium . When these crystals are exposed to radiation , the dysprosium atoms become excited and luminescent . The luminescence can be measured to determine the degree of exposure to which the dosimeter has been subjected .

Nanofibers of dysprosium compounds have high strength and a large surface area . Therefore , they can be used to reinforce other materials and act as a catalyst . Fibers of dysprosium oxide fluoride can be produced by heating an aqueous solution of DyBr3 and NaF to 450 ° C at 450 bar for 17 hours . This material is remarkably robust , surviving over 100 hours in various aqueous solutions at temperatures exceeding 400 ° C without redissolving or aggregating .

Dysprosium iodide and dysprosium bromide are used in high @-@ intensity metal @-@ halide lamps . These compounds dissociate near the hot center of the lamp , releasing isolated dysprosium atoms . The latter re @-@ emit light in the green and red part of the spectrum , thereby effectively producing bright light .

Several paramagnetic crystal salts of dysprosium (Dysprosium Gallium Garnet , DGG ; Dysprosium Aluminum Garnet , DAG ; Dysprosium Iron Garnet , DyIG) are used in adiabatic demagnetization refrigerators .

= = Precautions = =

Like many powders , dysprosium powder may present an explosion hazard when mixed with air and when an ignition source is present . Thin foils of the substance can also be ignited by sparks or by static electricity . Dysprosium fires cannot be put out by water . It can react with water to produce flammable hydrogen gas . Dysprosium chloride fires , however , can be extinguished with water , while dysprosium fluoride and dysprosium oxide are non @-@ flammable . Dysprosium nitrate , Dy (NO3) 3 , is a strong oxidizing agent and will readily ignite on contact with organic substances .

Soluble dysprosium salts , such as dysprosium chloride and dysprosium nitrate , are mildly toxic when ingested . Based on the toxicity of dysprosium chloride to mice , it is estimated that the ingestion of 500 grams or more could be fatal to a human . The insoluble salts , however , are non @-@ toxic .