Yttrium

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Yttrium is a chemical element with symbol **Y** and atomic number 39. It is a silvery-metallic transition metal chemically similar to the lanthanides and has often been classified as a "rare earth element".[3] Yttrium is almost always found in combination with lanthanide elements in rare earth minerals, and is never found in nature as a free element. ^{89}Y is the only stable isotope, and the only isotope found in the Earth's crust.

In 1787, Carl Axel Arrhenius found a new mineral near Ytterby in Sweden and named it *ytterbite*, after the village. Johan Gadolin discovered yttrium's oxide in Arrhenius' sample in 1789,[4] and Anders Gustaf Ekeberg named the new oxide *yttria*. Elemental yttrium was first isolated in 1828 by Friedrich Wöhler.[5]

The most important uses of yttrium are LEDs and phosphors, particularly the red phosphors in television set cathode ray tube (CRT) displays.[6] Yttrium is also used in the production of electrodes, electrolytes, electronic filters, lasers, superconductors, various medical applications, and tracing various materials to enhance their properties.

Yttrium has no known biological role and exposure to yttrium compounds can cause lung disease in humans.[7]

Characteristics

Properties

Yttrium is a soft, silver-metallic, lustrous and highly crystalline transition metal in group 3. As expected by periodic trends, it is less electronegative than its predecessor in the group, scandium, and less electronegative than the next member of period 5, zirconium; additionally, it is of comparable electronegativity to its successor in its group, lutetium, due to the lanthanide contraction.[8][9] Yttrium is the first d-block element in the fifth period.

Yttrium, $_{39}$Y

General properties	
Name, symbol	yttrium, Y
Appearance	silvery white
Yttrium in the periodic table	
Atomic number (Z)	39
Group, block	group 3, d-block
Period	period 5
Element category	transition metal
Standard atomic weight (±) (A_r)	88.90584(2)[1]
Electron configuration	[Kr] $4d^1 5s^2$
per shell	2, 8, 18, 9, 2
Physical properties	
Phase	solid
Melting point	1799 K (1526 °C, 2779 °F)
Boiling point	3203 K (2930 °C, 5306 °F)
Density near r.t.	4.472 g/cm^3

The pure element is relatively stable in air in bulk form, due to passivation of a protective oxide (Y_2O_3) film that forms on the surface. This film can reach a thickness of 10 µm when yttrium is heated to 750 °C in water vapor.[10] When finely divided, however, yttrium is very unstable in air; shavings or turnings of the metal can ignite in air at temperatures exceeding 400 °C.[5] Yttrium nitride (YN) is formed when the metal is heated to 1000 °C in nitrogen.[10]

Similarity to the lanthanides

The similarities of yttrium to the lanthanides are so strong that the element has historically been grouped with them as a rare earth element,[3] and is always found in nature together with them in rare earth minerals.[11] Chemically, yttrium resembles those elements more closely than its neighbor in the periodic table, scandium,[12] and if physical properties were plotted against atomic number, it would have an apparent number of 64.5 to 67.5, placing it between the lanthanides gadolinium and erbium.[13]

It often also falls in the same range for reaction order,[10] resembling terbium and dysprosium in its chemical reactivity.[6] Yttrium is so close in size to the so-called 'yttrium group' of heavy lanthanide ions that in solution, it behaves as if it were one of them.[10][14] Even though the lanthanides are one row farther down the periodic table than yttrium, the similarity in atomic radius may be attributed to the lanthanide contraction.[15]

One of the few notable differences between the chemistry of yttrium and that of the lanthanides is that yttrium is almost exclusively trivalent, whereas about half the lanthanides can have valences other than three.[10]

Compounds and reactions

As a trivalent transition metal, yttrium forms various inorganic compounds, generally in the oxidation state of +3, by giving up all three of its valence electrons.[16] A good example is yttrium(III) oxide (Y_2O_3), also known as yttria, a six-coordinate white solid.[17]

when liquid, at m.p.	4.24 g/cm^3
Heat of fusion	11.42 kJ/mol
Heat of vaporization	363 kJ/mol
Molar heat capacity	26.53 J/(mol·K)

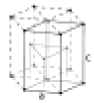
Vapor pressure

P (Pa)	**1**	**10**	**100**	**1 k**	**10 k**	**100 k**
at T (K)	1883	2075	(2320)	(2627)	(3036)	(3607)

Atomic properties

Oxidation states	**3**, 2, 1 (a weakly basic oxide)
Electronegativity	Pauling scale: 1.22
Ionization energies	1st: 600 kJ/mol 2nd: 1180 kJ/mol 3rd: 1980 kJ/mol
Atomic radius	empirical: 180 pm
Covalent radius	190±7 pm

Miscellanea

Crystal structure	hexagonal close-packed (hcp) 
Speed of sound thin rod	3300 m/s (at 20 °C)
Thermal expansion	α, poly: 10.6 µm/(m·K) (at r.t.)
Thermal conductivity	17.2 W/(m·K)
Electrical resistivity	α, poly: 596 nΩ·m (at r.t.)
Magnetic ordering	paramagnetic[2]
Young's modulus	63.5 GPa

Yttrium forms a water-insoluble fluoride, hydroxide, and oxalate, but its bromide, chloride, iodide, nitrate and sulfate are all soluble in water.[10] The Y^{3+} ion is colorless in solution because of the absence of electrons in the d and f electron shells.[10]

Water readily reacts with yttrium and its compounds to form Y_2O_3.[11] Concentrated nitric and hydrofluoric acids do not rapidly attack yttrium, but other strong acids do.[10]

With halogens, yttrium forms trihalides such as yttrium(III) fluoride (YF_3), yttrium(III) chloride (YCl_3), and yttrium(III) bromide (YBr_3) at temperatures above roughly 200 °C.[7] Similarly, carbon, phosphorus, selenium, silicon and sulfur all form binary compounds with yttrium at elevated temperatures.[10]

Organoyttrium chemistry is the study of compounds containing carbon–yttrium bonds. A few of these are known to have yttrium in the oxidation state 0.[18][19] (The +2 state has been observed in chloride melts,[20] and +1 in oxide clusters in the gas phase.[21]) Some trimerization reactions were generated with organoyttrium compounds as catalysts.[19] These syntheses use YCl_3 as a starting material, obtained from Y_2O_3 and concentrated hydrochloric acid and ammonium chloride.[22][23]

Hapticity is a term to describe the coordination of a group of contiguous atoms of a ligand bound to the central atom; it is indicated by the Greek character *eta*, η. Yttrium complexes were the first examples of complexes where carboranyl ligands were bound to a d^0-metal center through a η^7-hapticity.[19] Vaporization of the graphite intercalation compounds graphite–Y or graphite–Y_2O_3 leads to the formation of endohedral fullerenes such as $Y@C_{82}$.[6] Electron spin resonance studies indicated the formation of Y^{3+} and $(C_{82})^{3-}$ ion pairs.[6] The carbides Y_3C, Y_2C, and YC_2 can be hydrolyzed to form hydrocarbons.[10]

Shear modulus	25.6 GPa
Bulk modulus	41.2 GPa
Poisson ratio	0.243
Brinell hardness	200–589 MPa
CAS Number	7440-65-5
History	
Naming	after Ytterby (Sweden) and its mineral ytterbite (gadolinite)
Discovery	Johan Gadolin (1794)
First isolation	Carl Gustav Mosander (1842)

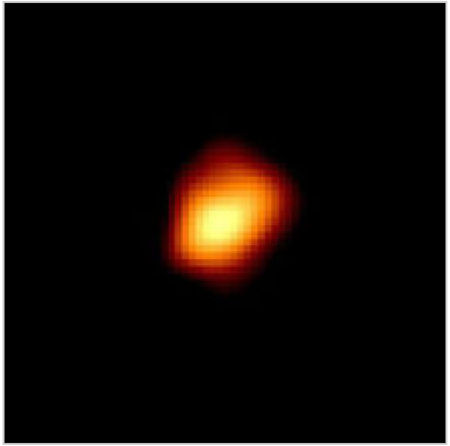
Most stable isotopes of yttrium

iso	NA	half-life	DM	DE (MeV)	DP
^{87}Y	syn	3.35 d	ε	–	^{87}Sr
			γ	0.48, 0.38D	–
^{88}Y	syn	106.6 d	ε	–	^{88}Sr
			γ	1.83, 0.89	–
^{89}Y	100%	is stable with 50 neutrons			
^{90}Y	syn	2.67 d	β^-	2.28	^{90}Zr
			γ	2.18	–
^{91}Y	syn	58.5 d	β^-	1.54	^{91}Zr
			γ	1.20	–

Nucleosynthesis and isotopes

Yttrium in the Solar System was created through stellar nucleosynthesis, mostly by the s-process (≈72%), but also by the r-process (≈28%).[24] The r-process consists of rapid neutron capture of lighter elements during supernova explosions. The s-process is a slow neutron capture of lighter elements inside pulsating red giant stars.[25]

Yttrium isotopes are among the most common products of the nuclear fission of uranium in nuclear explosions and nuclear reactors. In the context of nuclear waste management, the most important isotopes of yttrium are ^{91}Y and ^{90}Y, with half-lives of 58.51 days and 64 hours, respectively.[26] Though ^{90}Y has a short half-life, it exists in secular equilibrium with its long-lived parent isotope, strontium-90 (^{90}Sr) with a half-life of 29 years.[5]



Mira is an example of the type of red giant star where most of the yttrium in the solar system was created

All group 3 elements have an odd atomic number, and therefore few stable isotopes.[8] Scandium has one stable isotope, and yttrium itself has only one stable isotope, ^{89}Y, is also the only isotope that occurs naturally. However, the lanthanide rare earths contain elements of even atomic number and many stable isotopes. Yttrium-89 is thought to be more abundant than it otherwise would be, due in part to the s-process, which allows enough time for isotopes created by other processes to decay by electron emission (neutron → proton).[25][note 1] Such a slow process tends to favor isotopes with atomic mass numbers (A = protons + neutrons) around 90, 138 and 208, which have unusually stable atomic nuclei with 50, 82, and 126 neutrons, respectively.[25][note 2][5] ^{89}Y has a mass number close to 90 and has 50 neutrons in its nucleus.

At least 32 synthetic isotopes of yttrium have been observed, and these range in atomic mass number from 76 to 108.[26] The least stable of these is ^{106}Y with a half-life of >150 ns (^{76}Y has a half-life of >200 ns) and the most stable is ^{88}Y with a half-life of 106.626 days.[26] Apart from the isotopes ^{91}Y, ^{87}Y, and ^{90}Y, with half-lives of 58.51 days, 79.8 hours, and 64 hours, respectively, all the other isotopes have half-lives of less than a day and most of less than an hour.[26]

Yttrium isotopes with mass numbers at or below 88 decay primarily by positron emission (proton → neutron) to form strontium (Z = 38) isotopes.[26] Yttrium isotopes with mass numbers at or above 90 decay primarily by electron emission (neutron → proton) to form zirconium (Z = 40) isotopes.[26] Isotopes with mass numbers at or above 97 are also known to have minor decay paths of β^- delayed neutron emission.[27]

Yttrium has at least 20 metastable ("excited") isomers ranging in mass number from 78 to 102.[26][note 3] Multiple excitation states have been observed for ^{80}Y and ^{97}Y.[26] While most of yttrium's isomers are expected to be less stable than their ground state, ^{78m}Y, ^{84m}Y, ^{85m}Y, ^{96m}Y, ^{98m1}Y, ^{100m}Y, and ^{102m}Y have longer half-lives than their ground states, as these isomers decay by beta decay rather than isomeric transition.[27]

Source

- Wikipedia: Yttrium (https://en.wikipedia.org/wiki/Yttrium)