Rhenium

From Wikipedia, the free encyclopedia

Rhenium is a chemical element with symbol **Re** and atomic number 75. It is a silvery-white, heavy, third-row transition metal in group 7 of the periodic table. With an estimated average concentration of 1 part per billion (ppb), rhenium is one of the rarest elements in the Earth's crust. The free element has the third-highest melting point and highest boiling point of any element at 5873 K. Rhenium resembles manganese and technetium chemically and is mainly obtained as a by-product of the extraction and refinement of molybdenum and copper ores. Rhenium shows in its compounds a wide variety of oxidation states ranging from −1 to +7.

Discovered in 1925, rhenium was the last stable element to be discovered. It was named after the river Rhine in Europe.

Nickel-based superalloys of rhenium are used in the combustion chambers, turbine blades, and exhaust nozzles of jet engines. These alloys contain up to 6% rhenium, making jet engine construction the largest single use for the element, with the chemical industry's catalytic uses being next-most important. Because of the low availability relative to demand, rhenium is expensive, with an average price of approximately US$2,750 per kilogram (US$85.53 per troy ounce) as of April 2015; it is also of critical strategic military importance, for its use in high performance military jet and rocket engines.[3]

Characteristics

Rhenium is a silvery-white metal with one of the highest melting points of all elements, exceeded by only tungsten and carbon. It also has one of the highest boiling point of all elements. It is also one of the densest, exceeded only by platinum, iridium and osmium. Rhenium has a hexagonal close-packed crystal structure, with lattice parameters a = 276.1 pm and c = 445.6 pm.[13]

Its usual commercial form is a powder, but this element can be consolidated by pressing and sintering in a vacuum or hydrogen atmosphere. This procedure yields a compact solid having a density above 90% of the density of the metal.

Rhenium, $_{75}$Re

General properties	
Name, symbol	rhenium, Re
Appearance	silvery-grayish
Rhenium in the periodic table	
Atomic number (Z)	75
Group, block	group 7, d-block
Period	period 6
Element category	transition metal
Standard atomic weight (±) (A_r)	186.207(1)[1]
Electron configuration	[Xe] $4f^{14}$ $5d^5$ $6s^2$
per shell	2, 8, 18, 32, 13, 2
Physical properties	
Phase	solid
Melting point	3459 K (3186 °C, 5767 °F)
Boiling point	5903 K (5630 °C, 10,170 °F)
Density near r.t.	21.02 g/cm^3

When annealed this metal is very ductile and can be bent, coiled, or rolled.[14] Rhenium-molybdenum alloys are superconductive at 10 K; tungsten-rhenium alloys are also superconductive[15] around 4–8 K, depending on the alloy. Rhenium metal superconducts at 1.697 ± 0.006 K.[16] [17]

In bulk form and at room temperature and atmospheric pressure, the element resists alkalis, sulfuric acid, hydrochloric acid, dilute (but not concentrated) nitric acid, and aqua regia.

Isotopes

Rhenium has one stable isotope, rhenium-185, which nevertheless occurs in minority abundance, a situation found only in two other elements (indium and tellurium). Naturally occurring rhenium is only 37.4% ^{185}Re, and 62.6% ^{187}Re, which is unstable but has a very long half-life (≈10^{10} years). This lifetime can be greatly affected by the charge state of rhenium atom.[18][19] The beta decay of ^{187}Re is used for rhenium-osmium dating of ores. The available energy for this beta decay (2.6 keV) is one of the lowest known among all radionuclides. The isotope rhenium-186m is notable as being one of the longest lived metastable isotopes with a half-life of around 200,000 years. There are twenty-five other recognized radioactive isotopes of rhenium.[20]

Compounds

Rhenium compounds are known for all the oxidation states between −3 and +7 except −2. The oxidation states +7, +6, +4, and +2 are the most common.[21] Rhenium is most available commercially as salts of perrhenate, including sodium and ammonium perrhenates. These are white, water-soluble compounds.[22]

Halides and oxyhalides

when liquid, at m.p.	18.9 g/cm^3
Heat of fusion	60.43 kJ/mol
Heat of vaporization	704 kJ/mol
Molar heat capacity	25.48 J/(mol·K)

Vapor pressure

P (Pa)	**1**	**10**	**100**	**1 k**	**10 k**	**100 k**
at T (K)	3303	3614	4009	4500	5127	5954

Atomic properties

Oxidation states	7, 6, 5, **4**, 3, 2, 1, 0, −1, −3 (a mildly acidic oxide)
Electronegativity	Pauling scale: 1.9
Ionization energies	1st: 760 kJ/mol 2nd: 1260 kJ/mol 3rd: 2510 kJ/mol (more)
Atomic radius	empirical: 137 pm
Covalent radius	151±7 pm

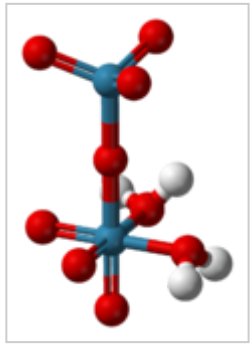
Miscellanea

Crystal structure	hexagonal close-packed (hcp) 
Speed of sound thin rod	4700 m/s (at 20 °C)
Thermal expansion	6.2 µm/(m·K)
Thermal conductivity	48.0 W/(m·K)
Electrical resistivity	193 nΩ·m (at 20 °C)
Magnetic ordering	paramagnetic[2]

The most common rhenium chlorides are $ReCl_6$, $ReCl_5$, $ReCl_4$, and $ReCl_3$.[23] The structures of these compounds often feature extensive Re-Re bonding, which is characteristic of this metal in oxidation states lower than VII. Salts of $[Re_2Cl_8]^{2-}$ feature a quadruple metal-metal bond. Although the highest rhenium chloride features Re(VI), fluorine gives the d^0 Re(VII) derivative rhenium heptafluoride. Bromides and iodides of rhenium are also well known.

Like tungsten and molybdenum, with which it shares chemical similarities, rhenium forms a variety of oxyhalides. The oxychlorides are most common, and include $ReOCl_4$, $ReOCl_3$.

Oxides and sulfides



Perrhenic acid adopts an unconventional structure.

The most common oxide is the volatile colourless Re_2O_7. Rhenium trioxide ReO_3 adopts a perovskite-like structure. Other oxides include Re_2O_5, ReO_2, and Re_2O_3.[23] The sulfides are ReS_2 and Re_2S_7. Perrhenate salts can be converted to tetrathioperrhenate by the action of ammonium hydrosulfide.[24]

Other compounds

Rhenium diboride (ReB_2) is a hard compound having the hardness similar to that of tungsten carbide, silicon carbide, titanium diboride or zirconium diboride.[25]

Organorhenium compounds

Dirhenium decacarbonyl is the most common entry to organorhenium chemistry. Its reduction with sodium amalgam gives $Na[Re(CO)_5]$ with rhenium in the formal oxidation state −1.[26] Dirhenium decacarbonyl can be oxidised with bromine to bromopentacarbonylrhenium(I):[27]

$$Re_2(CO)_{10} + Br_2 \rightarrow 2\ Re(CO)_5Br$$

Young's modulus	463 GPa
Shear modulus	178 GPa
Bulk modulus	370 GPa
Poisson ratio	0.30
Mohs hardness	7.0
Vickers hardness	1350–7850 MPa
Brinell hardness	1320–2500 MPa
CAS Number	7440-15-5
History	
Naming	after the river Rhine (German: *Rhein*)
Discovery	Masataka Ogawa (1908)
First isolation	Masataka Ogawa (1919)
Named by	Walter Noddack, Ida Noddack, Otto Berg (1925)

Most stable isotopes of rhenium

iso	NA	half-life	DM	DE (MeV)	DP
^{185}Re	37.4%	is stable with 110 neutrons			
^{187}Re	62.6%	4.12×10^{10} y	β^-	0.0026	^{187}Os

Reduction of this pentacarbonyl with zinc and acetic acid gives pentacarbonylhydridorhenium:[28]

$$Re(CO)_5Br + Zn + HOAc \rightarrow Re(CO)_5H + ZnBr(OAc)$$

Methylrhenium trioxide ("MTO"), CH_3ReO_3 is a volatile, colourless solid has been used as a catalyst in some laboratory experiments. It can be prepared by many routes, a typical method is the reaction of Re_2O_7 and tetramethyltin:

$$Re_2O_7 + (CH_3)_4Sn \rightarrow CH_3ReO_3 + (CH_3)_3SnOReO_3$$

Analogous alkyl and aryl derivatives are known. MTO catalyses for the oxidations with hydrogen peroxide. Terminal alkynes yield the corresponding acid or ester, internal alkynes yield diketones, and alkenes give epoxides. MTO also catalyses the conversion of aldehydes and diazoalkanes into an alkene.[29]

Nonahydridorhenate

A distinctive derivative of rhenium is nonahydridorhenate, originally thought to be the *rhenide* anion, Re^-, but actually containing the ReH_9^{2-} anion in which the oxidation state of rhenium is +7.

Structure of ReH_9^{2-}.

Occurrence

Molybdenite

Rhenium is one of the rarest elements in Earth's crust with an average concentration of 1 ppb;[23] other sources quote the number of 0.5 ppb making it the 77th most abundant element in Earth's crust.[30] Rhenium is probably not found free in nature (its possible natural occurrence is uncertain), but occurs in amounts up to 0.2%[23] in the mineral molybdenite (which is primarily molybdenum disulfide), the major commercial source, although single molybdenite samples with up to 1.88% have been found.[31] Chile has the world's largest rhenium reserves, part of the copper ore deposits, and was the leading producer as of 2005.[32] It was only recently that the first rhenium mineral was found and described (in 1994), a rhenium sulfide mineral (ReS_2) condensing from a fumarole on Russia's Kudriavy volcano, Iturup island, in the Kuril Islands.[33] Kudryavy discharges up to 20–60 kg rhenium per year mostly in the form of rhenium disulfide.[34][35] Named rheniite, this rare mineral commands high prices among collectors.[36]

Source

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