

Iridium

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Iridium is a chemical element with symbol **Ir** and atomic number 77. A very hard, brittle, silvery-white transition metal of the platinum group, iridium is generally credited with being the second densest element (after osmium). It is also the most corrosion-resistant metal, even at temperatures as high as 2000 °C. Although only certain molten salts and halogens are corrosive to solid iridium, finely divided iridium dust is much more reactive and can be flammable.

Iridium was discovered in 1803 among insoluble impurities in natural platinum. Smithson Tennant, the primary discoverer, named iridium for the Greek goddess Iris, personification of the rainbow, because of the striking and diverse colors of its salts. Iridium is one of the rarest elements in Earth's crust, with annual production and consumption of only three tonnes. ¹⁹¹Ir and ¹⁹³Ir are the only two naturally occurring isotopes of iridium, as well as the only stable isotopes; the latter is the more abundant of the two.

The most important iridium compounds in use are the salts and acids it forms with chlorine, though iridium also forms a number of organometallic compounds used in industrial catalysis, and in research. Iridium metal is employed when high corrosion resistance at high temperatures is needed, as in high-performance spark plugs, crucibles for recrystallization of semiconductors at high temperatures, and electrodes for the production of chlorine in the chloralkali process. Iridium radioisotopes are used in some radioisotope thermoelectric generators.

Iridium is found in meteorites with an abundance much higher than its average abundance in Earth's crust.^[4] For this reason, the unusually high abundance of iridium in the clay layer at the Cretaceous–Paleogene boundary gave rise to the Alvarez hypothesis that the impact of a massive extraterrestrial object caused the extinction of dinosaurs and many other

Iridium, 77Ir



General properties

Name, symbol	iridium, Ir
Pronunciation	/ɪˈrɪdiəm/ <i>i-RID-ee-əm</i>
Appearance	silvery white

Iridium in the periodic table

Atomic number (<i>Z</i>)	77
Group, block	group 9, d-block
Period	period 6
Element category	 □ transition metal
Standard atomic weight (<i>±</i>) (<i>A</i> _r)	192.217(3) ^[1]
Electron configuration	[Xe] 4f ¹⁴ 5d ⁷ 6s ²
per shell	2, 8, 18, 32, 15, 2

Physical properties

Phase	solid
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species 66 million years ago. Similarly, an iridium anomaly in core samples from the Pacific Ocean suggested the Eltanin impact of about 2.5 million years ago.

It is thought that the total amount of iridium in the planet Earth is much higher than that observed in crustal rocks, but as with other platinum-group metals, the high density and tendency of iridium to bond with iron caused most iridium to descend below the crust when the planet was young and still molten.

Characteristics

Physical properties

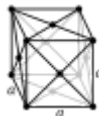


One troy ounce (31.1035 g) of arc-melted iridium

A member of the platinum group metals, iridium is white, resembling platinum, but with a slight yellowish cast. Because of its hardness, brittleness, and very high melting point, solid iridium is difficult to machine, form, or work, thus powder metallurgy is commonly employed, instead.^[5] It is the only metal to maintain good mechanical properties in air at temperatures above 1,600 °C (2,910 °F).^[6] It has the 10th highest boiling point among all elements and becomes a superconductor at temperatures below 0.14 K.^[7]

Iridium's modulus of elasticity is the second-highest among the metals, only being surpassed by osmium.^[6] This, together with a high shear modulus and a very low figure for Poisson's ratio (the relationship of longitudinal to lateral strain), indicate the high degree of stiffness and resistance to deformation that have rendered its fabrication into useful components a matter of great difficulty. Despite these limitations and

Melting point	2719 K (2446 °C, 4435 °F)					
Boiling point	4403 K (4130 °C, 7466 °F)					
Density near r.t.	22.56 g/cm ³					
when liquid, at m.p.	19 g/cm ³					
Heat of fusion	41.12 kJ/mol					
Heat of vaporization	564 kJ/mol					
Molar heat capacity	25.10 J/(mol·K)					
Vapor pressure						
P (Pa)	1	10	100	1 k	10 k	100 k
at T (K)	2713	2957	3252	3614	4069	4659
Atomic properties						
Oxidation states	−3, −1, 0, 1, 2, 3 , 4 , 5, 6, 7, 8, 9 ^[2]					
Electronegativity	Pauling scale: 2.20					
Ionization energies	1st: 880 kJ/mol 2nd: 1600 kJ/mol					
Atomic radius	empirical: 136 pm					
Covalent radius	141±6 pm					
Miscellanea						
Crystal structure	face-centered cubic (fcc)					
Speed of sound thin rod	4825 m/s (at 20 °C)					
Thermal expansion	6.4 μm/(m·K)					
Thermal conductivity	147 W/(m·K)					
Electrical resistivity	47.1 nΩ·m (at 20 °C)					
Magnetic ordering	paramagnetic ^[3]					



iridium's high cost, a number of applications have developed where mechanical strength is an essential factor in some of the extremely severe conditions encountered in modern technology.^[6]

The measured density of iridium is only slightly lower (by about 0.12%) than that of osmium, the densest element known.^{[8][9]} Some ambiguity occurred regarding which of the two elements was denser, due to the small size of the difference in density and difficulties in measuring it accurately,^[10] but, with increased accuracy in factors used for calculating density X-ray crystallographic data yielded densities of 22.56 g/cm³ for iridium and 22.59 g/cm³ for osmium.^[11]

Chemical properties

Iridium is the most corrosion-resistant metal known:^[12] it is not attacked by almost any acid, aqua regia, molten metals, or silicates at high temperatures. It can, however, be attacked by some molten salts, such as sodium cyanide and potassium cyanide,^[13] as well as oxygen and the halogens (particularly fluorine)^[14] at higher temperatures.^[15]

Compounds

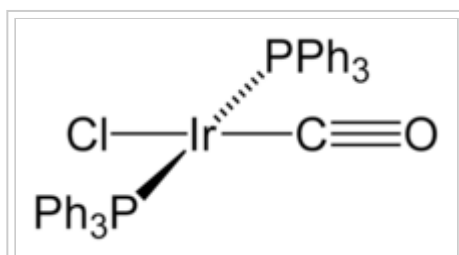
Iridium forms compounds in oxidation states between −3 and +9; the most common oxidation states are +3 and +4.^[5] Well-characterized examples of the high +6 oxidation state are rare, but include IrF₆ and two mixed oxides Sr₂MgIrO₆ and Sr₂CaIrO₆.^{[5][16]} In addition, it was reported in 2009 that iridium(VIII) oxide (IrO₄) was prepared under matrix isolation conditions (6 K in Ar) by UV irradiation of an iridium-peroxo complex. This species, however, is not expected to be stable as a bulk solid at higher temperatures.^[17] The highest oxidation state (+9), which is also the highest recorded for *any* element, is only known in one cation, IrO₄⁺; it is only known as gas-phase species and is not known to form any salts.^[2]

Young's modulus	528 GPa				
Shear modulus	210 GPa				
Bulk modulus	320 GPa				
Poisson ratio	0.26				
Mohs hardness	6.5				
Vickers hardness	1760–2200 MPa				
Brinell hardness	1670 MPa				
CAS Number	7439-88-5				
	History				
Discovery and first isolation	Smithson Tennant (1803)				
Most stable isotopes of iridium					
iso	NA	half-life	DM	DE (MeV)	DP
188Ir	syn	1.73 d	ε	1.64	188Os
189Ir	syn	13.2 d	ε	0.532	189Os
190Ir	syn	11.8 d	ε	2.000	190Os
191Ir	37.3%	is stable with 114 neutrons			
192Ir	syn	73.827 d	β [−]	1.460	192Pt
			ε	1.046	192Os
192m2Ir	syn	241 y	IT	0.161	192Ir
193Ir	62.7%	is stable with 116 neutrons			
193mIr	syn	10.5 d	IT	0.080	193Ir
194Ir	syn	19.3 h	β [−]	2.247	194Pt
194m2Ir	syn	171 d	IT	–	194Ir

Iridium dioxide, IrO_2 , a brown powder, is the only well-characterized oxide of iridium.^[5] A sesquioxide, Ir_2O_3 , has been described as a blue-black powder which is oxidized to IrO_2 by HNO_3 .^[14] The corresponding disulfides, diselenides, sesquisulfides, and sesquiselenides are known, and IrS_3 has also been reported.^[5] Iridium also forms iridates with oxidation states +4 and +5, such as K_2IrO_3 and KIrO_3 , which can be prepared from the reaction of potassium oxide or potassium superoxide with iridium at high temperatures.^[18]

Although no binary hydrides of iridium, Ir_xH_y are known, complexes are known that contain IrH_5^{4-} and IrH_6^{3-} , where iridium has the +1 and +3 oxidation states, respectively.^[19] The ternary hydride $\text{Mg}_6\text{Ir}_2\text{H}_{11}$ is believed to contain both the IrH_5^{4-} and the 18-electron IrH_4^{5-} anion.^[20]

No monohalides or dihalides are known, whereas trihalides, IrX_3 , are known for all of the halogens.^[5] For oxidation states +4 and above, only the tetrafluoride, pentafluoride and hexafluoride are known.^[5] Iridium hexafluoride, IrF_6 , is a volatile and highly reactive yellow solid, composed of octahedral molecules. It decomposes in water and is reduced to IrF_4 , a crystalline solid, by iridium black.^[5] Iridium pentafluoride has similar properties but it is actually a tetramer, Ir_4F_{20} , formed by four corner-sharing octahedra.^[5] Iridium metal dissolves in molten alkali-metal cyanides to produce the $\text{Ir}(\text{CN})_6^{3+}$ (hexacyanoiridate) ion.



Vaska's complex

Hexachloroiridic(IV) acid, H_2IrCl_6 , and its ammonium salt are the most important iridium compounds from an industrial perspective.^[21] They are involved in the purification of iridium and used as precursors for most other iridium compounds, as well as in the preparation of anode coatings. The IrCl_6^{2-} ion has an intense dark brown color, and can be readily reduced to the lighter-colored IrCl_6^{3-} and vice versa.^[21] Iridium trichloride, IrCl_3 , which can be obtained in anhydrous form from direct oxidation of iridium powder by chlorine at 650 °C,^[21] or in hydrated form by dissolving Ir_2O_3 in hydrochloric acid, is often used as a starting material for the synthesis of other Ir(III) compounds.^[5] Another compound used as a starting material is ammonium

hexachloroiridate(III), $(\text{NH}_4)_3\text{IrCl}_6$. Iridium(III) complexes are diamagnetic (low-spin) and generally have an octahedral molecular geometry.^[5]

Organoiridium compounds contain iridium-carbon bonds where the metal is usually in lower oxidation states. For example, oxidation state zero is found in tetrairidium dodecacarbonyl, $\text{Ir}_4(\text{CO})_{12}$, which is the most common and stable binary carbonyl of iridium.^[5] In this compound, each of the iridium atoms is bonded to the other three, forming a tetrahedral cluster. Some organometallic Ir(I) compounds are notable enough to be named after their discoverers. One is Vaska's complex,

$\text{IrCl}(\text{CO})[\text{P}(\text{C}_6\text{H}_5)_3]_2$, which has the unusual property of binding to the dioxygen molecule, O_2 .^[22] Another one is Crabtree's catalyst, a homogeneous catalyst for hydrogenation reactions.^[23] These compounds are both square planar, d^8 complexes, with a total of 16 valence electrons, which accounts for their reactivity.^[24]

An iridium-based organic LED material has been documented, and found to be much brighter than DPA or PPV, so could be the basis for flexible OLED lighting in the future.^[25]

Isotopes

Iridium has two naturally occurring, stable isotopes, ^{191}Ir and ^{193}Ir , with natural abundances of 37.3% and 62.7%, respectively.^[26] At least 34 radioisotopes have also been synthesized, ranging in mass number from 164 to 199. ^{192}Ir , which falls between the two stable isotopes, is the most stable radioisotope, with a half-life of 73.827 days, and finds application in brachytherapy^[27] and in industrial radiography, particularly for nondestructive testing of welds in steel in the oil and gas industries; iridium-192 sources have been involved in a number of radiological accidents. Three other isotopes have half-lives of at least a day— ^{188}Ir , ^{189}Ir , and ^{190}Ir .^[26] Isotopes with masses below 191 decay by some combination of β^+ decay, α decay, and (rare) proton emission, with the exceptions of ^{189}Ir , which decays by electron capture. Synthetic isotopes heavier than 191 decay by β^- decay, although ^{192}Ir also has a minor electron capture decay path.^[26] All known isotopes of iridium were discovered between 1934 and 2001; the most recent is ^{171}Ir .^[28]

At least 32 metastable isomers have been characterized, ranging in mass number from 164 to 197. The most stable of these is $^{192\text{m}2}\text{Ir}$, which decays by isomeric transition with a half-life of 241 years,^[26] making it more stable than any of iridium's synthetic isotopes in their ground states. The least stable isomer is $^{190\text{m}3}\text{Ir}$ with a half-life of only 2 μs .^[26] The isotope ^{191}Ir was the first one of any element to be shown to present a Mössbauer effect. This renders it useful for Mössbauer spectroscopy for research in physics, chemistry, biochemistry, metallurgy, and mineralogy.^[29]

External links

- Wikipedia: Iridium (<https://en.wikipedia.org/wiki/Iridium>)