Protactinium

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Protactinium or **protoactinium** (former name) is a chemical element with symbol **Pa** and atomic number 91. It is a dense, silvery-gray metal which readily reacts with oxygen, water vapor and inorganic acids. It forms various chemical compounds where protactinium is usually present in the oxidation state +5, but can also assume +4 and even +2 or +3 states. The average concentrations of protactinium in the Earth's crust is typically on the order of a few parts per trillion, but may reach up to a few parts per million in some uraninite ore deposits. Because of its scarcity, high radioactivity and high toxicity, there are currently no uses for protactinium outside of scientific research, and for this purpose, protactinium is mostly extracted from spent nuclear fuel.

Protactinium was first identified in 1913 by Kasimir Fajans and Oswald Helmuth Göhring and named *brevium* because of the short half-life of the specific isotope studied, namely protactinium-234. A more stable isotope (^{231}Pa) of protactinium was discovered in 1917/18 by Otto Hahn and Lise Meitner, and they chose the name proto-actinium, but then the IUPAC named it finally protactinium in 1949 and confirmed Hahn and Meitner as discoverers. The new name meant "parent of actinium" and reflected the fact that actinium is a product of radioactive decay of protactinium. It is noted that John Arnold Cranston (working with Frederick Soddy and Ada Hitchins) is also credited with discovering the most stable isotope in 1915 but delayed his announcement due to being called up for service in the First World War.[5]

The longest-lived and most abundant (nearly 100%) naturally occurring isotope of protactinium, protactinium-231, has a half-life of 32,760 years and is a decay product of uranium-235. Much smaller trace amounts of the short-lived nuclear isomer protactinium-234m occur in the decay chain of uranium-238. Protactinium-233 results from the decay of thorium-233 as part of the chain of events used to produce uranium-233 by neutron irradiation of thorium-232. It is an undesired intermediate product in thorium-based nuclear reactors and is therefore removed from the active zone of the reactor during the breeding process. Analysis of the

Protactinium, $_{91}$Pa

General properties	
Name, symbol	protactinium, Pa
Pronunciation	/ˌproʊtækˈtɪniəm/ *PROH-tak-TIN-ee-əm*
Appearance	bright, silvery metallic luster
Protactinium in the periodic table	
Atomic number (*Z*)	91
Group, block	group n/a, f-block
Period	period 7
Element category	□ actinide
Standard atomic weight (±) (A_r)	231.03588(2)[1]
Electron configuration	[Rn] $5f^2$ $6d^1$ $7s^2$
per shell	2, 8, 18, 32, 20, 9, 2
Physical properties	
Phase	solid

relative concentrations of various uranium, thorium and protactinium isotopes in water and minerals is used in radiometric dating of sediments which are up to 175,000 years old and in modeling of various geological processes.

Isotopes

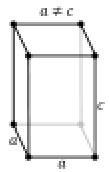
Twenty-nine radioisotopes of protactinium have been discovered, the most stable being ^{231}Pa with a half-life of 32,760 years, ^{233}Pa with a half-life of 27 days, and ^{230}Pa with a half-life of 17.4 days. All of the remaining isotopes have half-lives shorter than 1.6 days, and the majority of these have half-lives less than 1.8 seconds. Protactinium also has two nuclear isomers, ^{217m}Pa (half-life 1.2 milliseconds) and ^{234m}Pa (half-life 1.17 minutes).[23]

The primary decay mode for isotopes of protactinium lighter than (and including) the most stable isotope ^{231}Pa (i.e., ^{212}Pa to ^{231}Pa) is alpha decay and the primary mode for the heavier isotopes (i.e., ^{232}Pa to ^{240}Pa) is beta decay. The primary decay products of isotopes of protactinium lighter than (and including) ^{231}Pa are actinium isotopes and the primary decay products for the heavier isotopes of protactinium are uranium isotopes.[23]

Occurrence

Protactinium is one of the rarest and most expensive naturally occurring elements. It is found in the form of two isotopes – ^{231}Pa and ^{234}Pa, with the isotope ^{234}Pa occurring in two different energy states. Nearly all natural protactinium is protactinium-231. It is an alpha emitter and is formed by the decay of uranium-235, whereas the beta radiating protactinium-234 is produced as a result of uranium-238 decay. Nearly all uranium-238 (99.8%) decays first to the ^{234m}Pa isomer.[24]

Protactinium occurs in uraninite (pitchblende) at concentrations of about 0.3-3 parts ^{231}Pa per million parts (ppm) of ore.[6] Whereas the usual content is closer to 0.3 ppm[25] (e.g. in Jáchymov, Czech Republic[26]), some ores from the Democratic Republic of the Congo have about 3 ppm.[16] Protactinium is homogeneously

Melting point	1841 K (1568 °C, 2854 °F)
Boiling point	4300 K (4027 °C, 7280 °F) (?)
Density near r.t.	15.37 g/cm^3
Heat of fusion	12.34 kJ/mol
Heat of vaporization	481 kJ/mol
Atomic properties	
Oxidation states	2, 3, 4, **5** (a weakly basic oxide)
Electronegativity	Pauling scale: 1.5
Ionization energies	1st: 568 kJ/mol
Atomic radius	empirical: 163 pm
Covalent radius	200 pm
Miscellanea	
Crystal structure	tetragonal[2] 
Thermal expansion	~9.9 µm/(m·K)[3] (at r.t.)
Thermal conductivity	47 W/(m·K)
Electrical resistivity	177 nΩ·m (at 0 °C)
Magnetic ordering	paramagnetic[4]
CAS Number	7440-13-3
History	
Prediction	Dmitri Mendeleev (1869)

dispersed in most natural materials and in water, but at much lower concentrations on the order of one part per trillion, that corresponds to the radioactivity of 0.1 picocuries (pCi)/g. There is about 500 times more protactinium in sandy soil particles than in water, even the water present in the same sample of soil. Much higher ratios of 2,000 and above are measured in loam soils and clays, such as bentonite.[24][27]

Discovery and first isolation	Kasimir Fajans and Oswald Helmuth Göhring (1913)
Named by	Otto Hahn and Lise Meitner (1917–8)

Most stable isotopes of protactinium

iso	NA	half-life	DM	DE (MeV)	DP
^{229}Pa	syn	1.5 d	ε	0.311	^{229}Th
^{230}Pa	syn	17.4 d	ε	1.310	^{230}Th
^{231}Pa	100%	3.276×10^4 y	α	5.150	^{227}Ac
^{232}Pa	syn	1.31 d	β−	1.337	^{232}U
^{233}Pa	trace	26.967 d	β−	0.5701	^{233}U
^{234}Pa	trace	6.75 h	β−	2.195	^{234}U
^{234m}Pa	trace	1.17 min	β−	2.29	^{234}U

In nuclear reactors

Two major protactinium isotopes, ^{231}Pa and ^{233}Pa, are produced from thorium in nuclear reactors; both are undesirable and are usually removed, thereby adding complexity to the reactor design and operation. In particular, ^{232}Th via (*n*,2*n*) reactions produces ^{231}Th which quickly (half-life 25.5 hours) decays to ^{231}Pa. The last isotope, while not a transuranic waste, has a long half-life of 32,760 years and is a major contributor to the long term radiotoxicity of spent nuclear fuel.[28]

Protactinium-233 is formed upon neutron capture by ^{232}Th. It further either decays to uranium-233 or captures another neutron and converts into the non-fissile uranium-234.[29] ^{233}Pa has a relatively long half-life of 27 days and high cross section for neutron capture (the so-called "neutron poison"). Thus instead of rapidly decaying to the useful ^{233}U, a significant fraction of ^{233}Pa converts to non-fissile isotopes and consumes neutrons, degrading the reactor efficiency. To avoid this, ^{233}Pa is extracted from the active zone of thorium molten salt reactors, during their operation, so that it only decays to ^{233}U. This is achieved using several meters tall columns of molten bismuth with lithium dissolved in it. In a simplified scenario, lithium selectively reduces protactinium salts to protactinium metal which is then extracted from the molten-salt cycle, and bismuth is merely a carrier. It is chosen because of its low melting point (271 °C), low vapor pressure, good solubility for lithium and actinides, and immiscibility with molten halides.[28]

Source

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