Ruthenium

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Ruthenium is a chemical element with symbol **Ru** and atomic number 44. It is a rare transition metal belonging to the platinum group of the periodic table. Like the other metals of the platinum group, ruthenium is inert to most other chemicals. The Baltic German scientist Karl Ernst Claus discovered the element in 1844 and named it after his homeland, the Russian Empire (one of Russia's Latin names is Ruthenia). Ruthenium is usually found as a minor component of platinum ores; the annual production is about 20 tonnes.[4] Most ruthenium produced is used in wear-resistant electrical contacts and thick-film resistors. A minor application for ruthenium is in platinum alloys and as a chemistry catalyst.

Characteristics

Physical properties

Gas phase grown crystals of ruthenium metal.

A polyvalent hard white metal, ruthenium is a member of the platinum group and is in group 8 of the periodic table:

Whereas all other group 8 elements have 2 electrons in the outermost shell, in ruthenium, the outermost shell has only one electron (the final electron is in a lower shell). This anomaly is observed in the neighboring metals, niobium (41), rhodium (45), and palladium (46).

Ruthenium has four crystal modifications and does not tarnish unless subject to high temperatures. Ruthenium dissolves in fused alkalis to give ruthenates (RuO_4^{2-}), is not attacked by acids (even aqua regia) but is attacked by halogens at high temperatures.[5] Indeed, ruthenium is most readily attacked by oxidizing agents.[6] Small amounts of ruthenium can increase the hardness of platinum and palladium. The corrosion

Ruthenium, $_{44}$Ru

General properties	
Name, symbol	ruthenium, Ru
Pronunciation	/ruːˈθiːniəm/ *roo-**THEE**-nee-əm*
Appearance	silvery white metallic
Ruthenium in the periodic table	
Atomic number (*Z*)	44
Group, block	group 8, d-block
Period	period 5
Element category	▯ transition metal
Standard atomic weight (±) (A_r)	101.07(2)[1]
Electron configuration	[Kr] $4d^7\ 5s^1$
per shell	2, 8, 18, 15, 1
Physical properties	
Melting point	2607 K (2334 °C, 4233 °F)
Boiling point	4423 K (4150 °C, 7502 °F)
Density near r.t.	

resistance of titanium is increased markedly by the addition of a small amount of ruthenium.[5] The metal can be plated by electroplating and by thermal decomposition. A ruthenium-molybdenum alloy is known to be superconductive at temperatures below 10.6 K.[5] Ruthenium is the last of the 4d transition metals that can assume the group oxidation state +8, and even then is less stable there than the heavier congener osmium: this is the first group from the left of the table where the second and third-row transition metals display notable differences in chemical behavior. Like iron but unlike osmium, ruthenium can form aqueous cations in its lower oxidation states of +2 and +3.[7]

Ruthenium is the first in a downward trend in the melting and boiling points and atomization enthalpy in the 4d transition metals after the maximum seen at molybdenum, because the 4d subshell is more than half full and the electrons are contributing less to metallic bonding. (Technetium, the previous element, has an exceptionally low value that is off the trend due to its half-filled $[Kr]4d^5 5s^2$ configuration, though the small amount of energy needed to excite it to a $[Kr]4d^6 5s^1$ configuration indicates that it is not as far off the trend in the 4d series as manganese in the 3d transition series.)[8] Unlike the lighter congener iron, ruthenium is paramagnetic at room temperature, as iron also is above its Curie point.[9]

The reduction potentials in acidic aqueous solution for some common ruthenium ions are shown below:[10]

0.455 V	$Ru^{2+} + 2e^-$	$\leftrightarrow Ru$
0.249 V	$Ru^{3+} + e^-$	$\leftrightarrow Ru^{2+}$
1.120 V	$RuO_2 + 4H^+ + 2e^-$	$\leftrightarrow Ru^{2+} + 2H_2O$
1.563 V	$RuO_4^{2-} + 8H^+ + 4e^-$	$\leftrightarrow Ru^{2+} + 4H_2O$
1.368 V	$RuO_4^- + 8H^+ + 5e^-$	$\leftrightarrow Ru^{2+} + 4H_2O$
1.387 V	$RuO_4 + 4H^+ + 4e^-$	$\leftrightarrow RuO_2 + 2H_2O$

Isotopes

	12.45 g/cm^3
when liquid, at m.p.	10.65 g/cm^3
Heat of fusion	38.59 kJ/mol
Heat of vaporization	619 kJ/mol
Molar heat capacity	24.06 J/(mol·K)

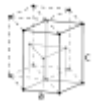
Vapor pressure

P (Pa)	**1**	**10**	**100**	**1 k**	**10 k**	**100 k**
at T (K)	2588	2811	3087	3424	3845	4388

Atomic properties

Oxidation states	-4, -2, 1,[2] 2, **3**, **4**, 5, 6, 7, 8 (a mildly acidic oxide)
Electronegativity	Pauling scale: 2.2
Ionization energies	1st: 710.2 kJ/mol 2nd: 1620 kJ/mol 3rd: 2747 kJ/mol
Atomic radius	empirical: 134 pm
Covalent radius	146±7 pm

Miscellanea

Crystal structure	hexagonal close-packed (hcp) 
Speed of sound thin rod	5970 m/s (at 20 °C)
Thermal expansion	6.4 µm/(m·K) (at 25 °C)
Thermal conductivity	117 W/(m·K)
Electrical resistivity	71 nΩ·m (at 0 °C)
Magnetic ordering	paramagnetic[3]

Naturally occurring ruthenium is composed of seven stable isotopes. Additionally, 34 radioactive isotopes have been discovered. Of these radioisotopes, the most stable are ^{106}Ru with a half-life of 373.59 days, ^{103}Ru with a half-life of 39.26 days and ^{97}Ru with a half-life of 2.9 days.[11][12]

Fifteen other radioisotopes have been characterized with atomic weights ranging from 89.93 u (^{90}Ru) to 114.928 u (^{115}Ru). Most of these have half-lives that are less than five minutes except ^{95}Ru (half-life: 1.643 hours) and ^{105}Ru (half-life: 4.44 hours).[11][12]

The primary decay mode before the most abundant isotope, ^{102}Ru, is electron capture and the primary mode after is beta emission. The primary decay product before ^{102}Ru is technetium and the primary decay product after is rhodium.[11][12]

Occurrence

As the 74th most abundant element in Earth's crust, ruthenium is relatively rare,[13] found in about 100 parts per trillion.[14] This element is generally found in ores with the other platinum group metals in the Ural Mountains and in North and South America. Small but commercially important quantities are also found in pentlandite extracted from Sudbury, Ontario, Canada, and in pyroxenite deposits in South Africa. The native form of ruthenium is a very rare mineral (Ir replaces part of Ru in its structure).[15][16]

Source

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

Young's modulus	447 GPa
Shear modulus	173 GPa
Bulk modulus	220 GPa
Poisson ratio	0.30
Mohs hardness	6.5
Brinell hardness	2160 MPa
CAS Number	7440-18-8
	History
Naming	after *Ruthenia* (Latin for: medieval Kyivska Rus' region)
Discovery and first isolation	Karl Ernst Claus (1844)

Most stable isotopes of ruthenium

iso	NA	half-life	DM	DE (MeV)	DP
^{96}Ru	5.54%	is stable with 52 neutrons			
^{97}Ru	syn	2.9 d	ε	–	^{97}Tc
			γ	0.215, 0.324	–
^{98}Ru	1.87%	is stable with 54 neutrons			
^{99}Ru	12.76%	is stable with 55 neutrons			
^{100}Ru	12.60%	is stable with 56 neutrons			
^{101}Ru	17.06%	is stable with 57 neutrons			
^{102}Ru	31.55%	is stable with 58 neutrons			
^{103}Ru	syn	39.26 d	β−	0.226	^{103}Rh
			γ	0.497	–
^{104}Ru	18.62%	is stable with 60 neutrons			
^{106}Ru	syn	373.59 d	β−	0.039	^{106}Rh