44

Ru

Ruthenium

101.07

Since WWII there has been much work on the chemistry of ruthenium.

The reason was the observation that ruthenium is one of the main products of the nuclear fission of heavy atoms.

Another and more recent reason has been the realization that many ruthenium complexes have unusual structures and reactivities, and that some have valuable or potentially valuable catalytic properties.

Ruthenium trichloride is by far the best starting material for the synthesis of compounds.

Overview

Name	Ruthenium
Symbol	Ru
Etymology	From “Ruthenia” meaning Russia
Atomic Number	44
Standard Atomic Weight	101.07
Metallic Category	Transition Metal
Group	8
Period	5
Block	d
Electron Configuration	[Kr] $4d^7$ $5s^1$

Characteristics

- Ruthenium is a very rare, hard, lustrous, brittle, silvery-white metal that does not tarnish at room temperature.
- It can exist in many oxidation states, its most common being the oxidation states II, III and IV.
- The metal is unaffected by air, water and acids.
- It reacts with molten alkali and halogens and can oxidize explosively.

Proton, Electron, Nuetron

No. of Protons (p^+)	44
No. of Electrons (e^-)	44
No. of Neutrons (n^0)	57

Reaction of ruthenium with air

Ruthenium is largely immune to atmospheric attack. On heating with oxygen, ruthenium metal gives ruthenium (IV) oxide, RuO_2.

$$Ru(s) + O_2(g) \rightarrow RuO_2(s)$$

Reaction of ruthenium with water

Ruthenium does not react with water under normal conditions.

Reaction of ruthenium with the halogens

Ruthenium reacts with excess of fluorine, F_2, to form ruthenium(VI) fluoride, RuF_6.

$$Ru(s) + 3F_2(g) \rightarrow RuF_6(s) \text{ (dark brown)}$$

Heating ruthenium metal at 330°C with chlorine, Cl_2, in the presence of carbon monoxide, CO, produces dark brown ruthenium (III) chloride, $RuCl_3$. Further heating of this material under Cl_2 gives a black form of ruthenium (III) chloride.

The Names Behind Ru

- The initial discovery of ruthenium was thought to have occurred in 1828, by Swedish chemist Jons Jacob Berzelius and Russian chemist Gottfried W. Osann.

- Later, in 1844, in Kazan, Russia, Karl K. Klaus repeated Osann's work to clarify the results. He was recognized as the discoverer of Ruthenium.

Physical Properties

Color	Silvery White Metallic
Density	12.45 g/cm^3
Melting Point	2607 K, 4233 °F 2334 °C
Boiling Point	7502 °F 4150 °C, 4423 K
Heat of Fusion	38.59 $kJ \cdot mol^{-1}$
Heat of Vaporization	591.6 $kJ \cdot mol^{-1}$
Molar Heat Capacity	24.06 $J \cdot mol^{-1} \cdot K^{-1}$

Vapor Pressure

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

Atomic Properties

Electronegativity	2.2 (Pauling scale)
Ionization Energies	1st: 710.2 $kJ \cdot mol^{-1}$ 2nd: 1620 $kJ \cdot mol^{-1}$ 3rd: 2747 $kJ \cdot mol^{-1}$
Atomic Radius	134 pm
Covalent Radius	146±7 pm

Magnetic Properties

Magnetic Type	Paramagnetic
Mass Magnetic Susceptibility	5.42×10^{-9}
Molar Magnetic Susceptibility	5.48×10^{-10}
Volume Magnetic Susceptibility	0.000067

Nuclear Properties

Half-Life	Stable
Lifetime	Stable
Quantum Numbers	$^{5}F_{5}$
Neutron Cross Section	2.6
Neutron Mass Absorption	0.0009
Known Isotopes	^{87}Ru, ^{88}Ru, ^{89}Ru, …, ^{118}Ru, ^{119}Ru, ^{120}Ru
Stable Isotopes	^{100}Ru, ^{101}Ru, ^{102}Ru, ^{104}Ru, ^{96}Ru, ^{98}Ru, ^{99}Ru
Some Isotopic Abundances	^{100}Ru 12.6%, ^{101}Ru 17.06% ^{102}Ru 31.55%, ^{104}Ru 18.62%

Abundances

- Abundance earth's crust: 1 part per billion by weight, 0.2 parts per billion by moles
- Abundance solar system: 5 parts per billion by weight, 0.06 parts per billion by moles
- Ruthenium is found free in nature often with the other platinum group metals.
- Commercially, it is obtained from pentlandite (a sulfide of iron and nickel) which contains small quantities of ruthenium.
- Ruthenium can also be extracted from spent nuclear fuel.

Production

❑ Mining

- ✓ 12 tonnes of Ruthenium is mined each year
- ✓ Obtained commercially as a by-product from nickel and copper mining

❑ From Used Nuclear Fuels

- ✓ Fission products of uranium-235 contain significant amounts of ruthenium and the lighter platinum group metals and therefore used nuclear fuel might be a possible source of ruthenium.

Some Important Uses

- Turbine Blades
- Electrical Catalyst
- Hardener for Palladium and Platinum
- Used in some Parker pen nibs
- Used for light absorption in dye-sensitized solar cells
- Data Storage (Chemical vapor deposition of ruthenium is used as a method to produce thin films of pure ruthenium on substrates.)

Jewelers back to black with rhodium, ruthenium

Ice-white platinum has long had enduring appeal in jewelry and experimental designers are now also turning to its lesser-known sister metals rhodium and ruthenium to produce work in darker hues.

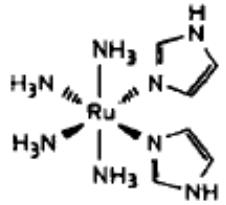
The deep gunmetal finish of black rhodium plate and the pure black of ruthenium are both becoming increasingly popular, jewelers say - a glossy, polished black.

Health Effects

- Ruthenium is a suspected carcinogen and its compounds strongly stain the skin. Ruthenium tetroxide (RuO_4) is highly toxic.

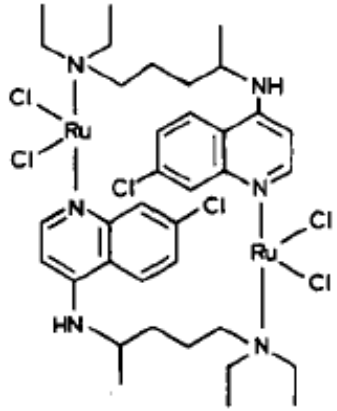
Ruthenium Compounds

Immunosuppressant



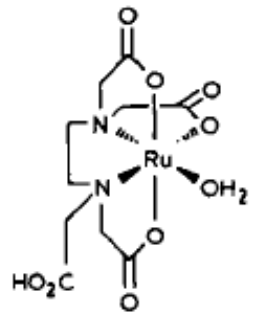
cis-$[Ru(NH_3)_4(Im)_2]$

Antimalarial



$[RuCl_2(chloroquine)]_2$

NO scavengers



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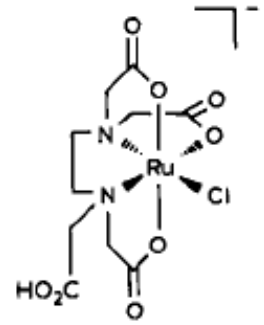

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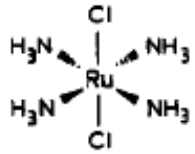
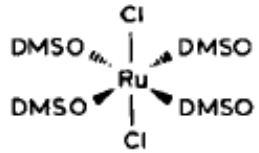
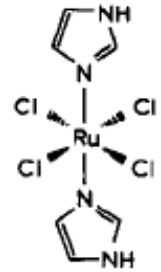
Anticancer



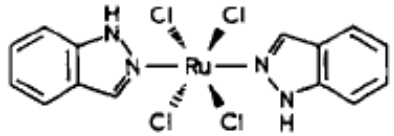
cis-$[RuCl_2(NH_3)_4]$



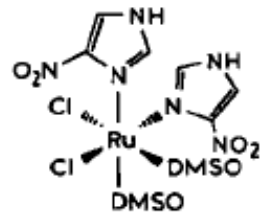
cis-$[RuCl_2(DMSO)_4]$



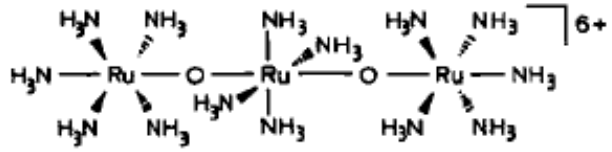
cis-$[RuCl_4(Im)_2]$



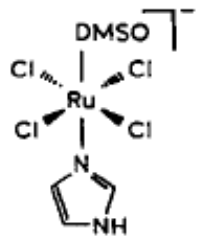
cis-$[RuCl_4(Indazole)_2]$



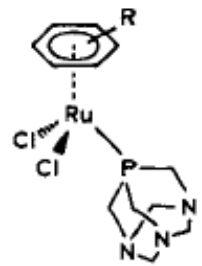
cis-$[RuCl_2(DMSO)_2(4\text{-}NO_2Im)_2]$



Ruthenium red



NAMI



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