= Rhodium =

Rhodium is a chemical element with symbol Rh and atomic number 45 . It is a rare , silvery @-@ white , hard , and chemically inert transition metal . It is a member of the platinum group . It has only one naturally occurring isotope , 103Rh . Naturally occurring rhodium is usually found as the free metal , alloyed with similar metals , and rarely as a chemical compound in minerals such as bowieite and rhodplumsite . It is one of the rarest and most valuable precious metals .

Rhodium is a noble metal , resistant to corrosion , found in platinum or nickel ores together with the other members of the platinum group metals . It was discovered in 1803 by William Hyde Wollaston in one such ore , and named for the rose color of one of its chlorine compounds , produced after it reacted with the powerful acid mixture aqua regia .

The element 's major use (approximately 80 % of world rhodium production) is as one of the catalysts in the three @-@ way catalytic converters in automobiles . Because rhodium metal is inert against corrosion and most aggressive chemicals , and because of its rarity , rhodium is usually alloyed with platinum or palladium and applied in high @-@ temperature and corrosion @-@ resistive coatings . White gold is often plated with a thin rhodium layer to improve its appearance while sterling silver is often rhodium @-@ plated for tarnish resistance .

Rhodium detectors are used in nuclear reactors to measure the neutron flux level .

= = History = =

Rhodium (Greek rhodon (?????) meaning " rose ") was discovered in 1803 by William Hyde Wollaston , soon after his discovery of palladium . He used crude platinum ore presumably obtained from South America . His procedure involved dissolving the ore in aqua regia and neutralizing the acid with sodium hydroxide (NaOH) . He then precipitated the platinum as ammonium chloroplatinate by adding ammonium chloride (NH

4Cl) . Most other metals like copper , lead , palladium and rhodium were precipitated with zinc . Diluted nitric acid dissolved all but palladium and rhodium , which were dissolved in aqua regia , and the rhodium was precipitated by the addition of sodium chloride as Na

3 [RhCl

6] · nH

2O . After being washed with ethanol , the rose @-@ red precipitate was reacted with zinc , which displaced the rhodium in the ionic compound and thereby released the rhodium as free metal .

After the discovery , the rare element had only minor applications ; for example , by the turn of the century , rhodium @-@ containing thermocouples were used to measure temperatures up to 1800 ° C. The first major application was electroplating for decorative uses and as corrosion @-@ resistant coating . The introduction of the three @-@ way catalytic converter by Volvo in 1976 increased the demand for rhodium . The previous catalytic converters used platinum or palladium , while the three @-@ way catalytic converter used rhodium to reduce the amount of NOx in the exhaust .

= = Characteristics = =

Rhodium is a hard , silvery , durable metal that has a high reflectance . Rhodium metal does not normally form an oxide , even when heated . Oxygen is absorbed from the atmosphere only at the melting point of rhodium , but is released on solidification . Rhodium has both a higher melting point and lower density than platinum . It is not attacked by most acids : it is completely insoluble in nitric acid and dissolves slightly in aqua regia .

= = = Chemical properties = = =

Rhodium belongs to group 9 of the periodic table , but the configuration of electrons in the outermost shells is atypical for the group . This anomaly is also observed in the neighboring elements , niobium (41) , ruthenium (44) , and palladium (46) .

The common oxidation state of rhodium is + 3 , but oxidation states from + 0 to + 6 are also observed .

Unlike ruthenium and osmium , rhodium forms no volatile oxygen compounds . The known stable oxides include Rh
2O
3 , RhO
2 , RhO
2 · xH
2O , Na
2RhO
3 , Sr
3LiRhO
6 and Sr
3NaRhO
6 . Halogen compounds are known in nearly the full range of possible oxidation states . Rhodium (III) chloride , rhodium (IV) fluoride , rhodium (V) fluoride and rhodium (VI) fluoride are examples . The lower oxidation states are stable only in the presence of ligands .

The best @-@ known rhodium @-@ halogen compound is the Wilkinson 's catalyst chlorotris (triphenylphosphine) rhodium (I) . This catalyst is used in the hydroformylation or hydrogenation of alkenes .

= = = Isotopes = = =

Naturally occurring rhodium is composed of only one isotope , 103Rh . The most stable radioisotopes are 101Rh with a half @-@ life of 3 @.@ 3 years , 102Rh with a half @-@ life of 207 days , 102mRh with a half @-@ life of 2 @.@ 9 years , and 99Rh with a half @-@ life of 16 @.@ 1 days . Twenty other radioisotopes have been characterized with atomic weights ranging from 92 @.@ 926 u (93Rh) to 116 @.@ 925 u (117Rh) . Most of these have half @-@ lives shorter than an hour , except 100Rh (20 @.@ 8 hours) and 105Rh (35 @.@ 36 hours) . It has numerous meta states , the most stable being 102mRh (0 @.@ 141 MeV) with a half @-@ life of about 2 @.@ 9 years and 101mRh (0 @.@ 157 MeV) with a half @-@ life of 4 @.@ 34 days (see isotopes of rhodium) .

In isotopes weighing less than 103 (the stable isotope) , the primary decay mode is electron capture and the primary decay product is ruthenium In isotopes greater than 103 , the primary decay mode is beta emission and the primary product is palladium .

= = Occurrence = =

Rhodium is one of the rarest elements in the Earth 's crust , comprising an estimated 0 @.@ 0002 parts per million (2 × 10 ? 10) . Its rarity affects its price and its use in commercial applications .

= = = Mining and price = = =

The industrial extraction of rhodium is complex because the ores mixed with other metals such as palladium , silver , platinum , and gold and there are very few rhodium @-@ bearing minerals . It is found in platinum ores and extracted as a white inert metal that is difficult to fuse . Principal sources are located in South Africa ; in river sands of the Ural Mountains ; and in North America , including the copper @-@ nickel sulfide mining area of the Sudbury , Ontario , region . Although the quantity at Sudbury is very small , the large amount of processed nickel ore makes rhodium recovery cost @-@ effective .

The main exporter of rhodium is South Africa (approximately 80 % in 2010) followed by Russia . The annual world production is 30 tonnes . The price of rhodium is highly variable . In 2007 , rhodium cost approximately eight times more than gold , 450 times more than silver , and 27 @,@

250 times more than copper by weight . In 2008 , the price briefly rose above $ 10 @,@ 000 per ounce ($ 350 @,@ 000 per kilogram) . The economic slowdown of the 3rd quarter of 2008 pushed rhodium prices sharply back below $ 1 @,@ 000 per ounce ($ 35 @,@ 000 per kilogram) ; the price rebounded to $ 2 @,@ 750 by early 2010 ($ 97 @,@ 000 per kilogram) (more than twice the gold price) , but in late 2013 , the prices were less than $ 1000 .

Political and financial problems led to very low oil prices and oversupply , causing most metals to drop in price . The economies of China , India and other emerging countries slowed in 2014 and 2015 . In 2014 alone , 23 @,@ 722 @,@ 890 motor vehicles were produced in China , excluding motorbikes . This resulted in a rhodium price of 740 @.@ 00 US- $ per Troy ounce (31 @.@ 1 grams) in late November 2015 .

= = = Used nuclear fuels = = =

Rhodium is a fission product of uranium @-@ 235 ; therefore , each kilogram of fission product contains a significant amount of the lighter platinum group metals including rhodium . Used nuclear fuel is a potential source of rhodium . However , the extraction is complex and expensive , and the presence of rhodium radioisotopes requires a period of cooling storage for multiple half @-@ lives of the longest @-@ lived isotope (about 10 years) . These factors make the source unattractive and no large @-@ scale extraction has been attempted .

= = Applications = =

The primary use of this element is in automobiles as a catalytic converter , changing harmful unburned hydrocarbons , carbon monoxide , and nitrogen oxide exhaust emissions into less noxious gases . Of 30 @,@ 000 kg of rhodium consumed worldwide in 2012 , 81 % (24 @,@ 300 kg) went into and 8 @,@ 060 kg was recovered from this application . About 964 kg of rhodium was used in the glass industry , mostly for production of fiberglass and flat @-@ panel glass , and 2 @,@ 520 kg was used in the chemical industry .

= = = Catalyst = = =

In 2012 , 81 % of the world production of rhodium was consumed in automobile catalytic converters . Rhodium is preferable to the other platinum metals in the reduction of nitrogen oxides to nitrogen and oxygen :

2 NOx ? x O
2 + N
2

Rhodium catalysts are used in a number of industrial processes , notably in catalytic carbonylation of methanol to produce acetic acid by the Monsanto process . It is also used to catalyze addition of hydrosilanes to molecular double bonds , a process important in manufacture of certain silicone rubbers . Rhodium catalysts are also used to reduce benzene to cyclohexane .

The complex of a rhodium ion with BINAP is a widely used chiral catalyst for chiral synthesis , as in the synthesis of menthol .

= = = Ornamental uses = = =

Rhodium finds use in jewelry and for decorations . It is electroplated on white gold and platinum to give it a reflective white surface at time of sale , after which the thin layer wears away with use . This is known as rhodium flashing in the jewelry business . It may also be used in coating sterling silver to protect against tarnish (silver sulfide , Ag2S , produced from atmospheric hydrogen sulfide , H2S) . Solid (pure) rhodium jewelry is very rare , more because of the difficulty of fabrication (high melting point and poor malleability) than because of the high price . The high cost ensures that rhodium is applied only as an electroplate .

Rhodium has also been used for honors or to signify elite status , when more commonly used metals such as silver , gold or platinum were deemed insufficient . In 1979 the Guinness Book of World Records gave Paul McCartney a rhodium @-@ plated disc for being history 's all @-@ time best @-@ selling songwriter and recording artist .

= = = Other uses = = =

Rhodium is used as an alloying agent for hardening and improving the corrosion resistance of platinum and palladium . These alloys are used in furnace windings , bushings for glass fiber production , thermocouple elements , electrodes for aircraft spark plugs , and laboratory crucibles . Other uses include :

Electrical contacts , where it is valued for small electrical resistance , small and stable contact resistance , and great corrosion resistance .

Rhodium plated by either electroplating or evaporation is extremely hard and useful for optical instruments .

Filters in mammography systems for the characteristic X @-@ rays it produces .

Rhodium neutron detectors are used in combustion engineering nuclear reactors to measure neutron flux levels ? this method requires a digital filter to determine the current neutron flux level , generating three separate signals : immediate , a few seconds delay , and a minute delay , each with its own signal level ; all three are combined in the rhodium detector signal . The three Palo Verde nuclear reactors each have 305 rhodium neutron detectors , 61 detectors on each of five vertical levels , providing an accurate 3D " picture " of reactivity and allowing fine tuning to consume the nuclear fuel most economically .

= = Precautions = =

Being a noble metal , pure rhodium is inert . However , chemical complexes of rhodium can be reactive . Median lethal dose (LD50) for rats is 198 mg of rhodium chloride ($RhCl_3$) per kilogram of body weight . Like the other noble metals , all of which are too inert to occur as chemical compounds in nature , rhodium has not been found to serve any biological function . In elemental form , the metal is harmless .

People can be exposed to rhodium in the workplace by inhalation . The Occupational Safety and Health Administration (OSHA) has specified the legal limit (Permissible exposure limit) for rhodium exposure in the workplace at 0 @.@ 1 mg / m3 over an 8 @-@ hour workday , and the National Institute for Occupational Safety and Health (NIOSH) has set the recommended exposure limit (REL) , at the same level . At levels of 100 mg / m3 , rhodium is immediately dangerous to life and health . For soluble compounds , the PEL and REL are both 0 @.@ 001 mg / m3 .