



Review on the Osmium market

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SMT Osmium beads (OsMWB)



SMT Osmium crystals (OsMWC)





Occurrence

The frequency of osmium in the earth's crust is about $5 \times 10^{-9} \%$. This means that on average 20 tons of the earth's crust contain about 1mg of osmium.

This makes osmium the rarest precious metal and the rarest metal at all in the earth's crust (Tab. 1).

Tab. 1 Content of the precious metals in the earth's crust

Metal	Content in earth crust
Silber	$7 \times 10^{-6} \%$
Gold	$3 \times 10^{-7} \%$
Palladium	$4 \times 10^{-8} \%$
Platin	$4 \times 10^{-8} \%$
Ruthenium	$1 \times 10^{-8} \%$
Rhodium	$6 \times 10^{-9} \%$
Iridium	$5 \times 10^{-9} \%$
Osmium	$5 \times 10^{-9} \%$

Osmium is mined together with platinum-rich nickel ores in South Africa, Russia and Canada.

Properties

Osmium is the element with the highest density [1]. Osmium has a density of 22.58 g/cm^3 , the second densest element iridium follows closely behind with 22.56 g/cm^3 . While osmium powder already oxidizes to the toxic osmium tetroxide at room temperature, compact osmium (such as beads or crystals) does not react appreciably with atmospheric oxygen to form osmium tetroxide until 600°C [2]. If the data of Fig. 1 is extrapolated to room temperature, the oxidation rate of Osmium beads (OsMWB) and crystals (OsMWC) is below 0,001mg per year. At room temperature, compact osmium does not pose any danger, e.g. it is also used to make jewelry [3].

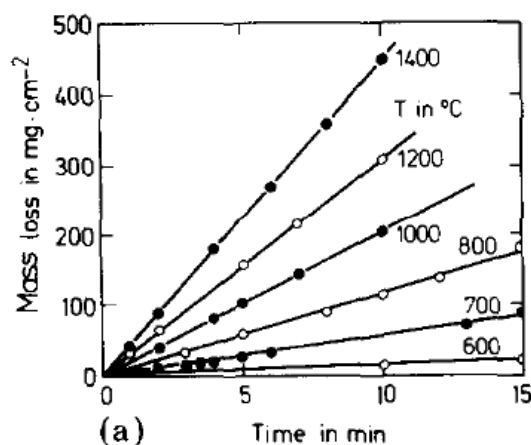


Fig. 2 Osmium oxidation rate in the temperature range $600\text{-}1400^\circ\text{C}$ [2]

Annual production

In 1971, estimations of the United States production of osmium as a byproduct of copper refining was 2000 troy ounces (62 kg). An additional 4169 troy ounces of osmium was toll-refined, resulting in a total production of 190 kg [4]

Due to the small traded quantities of osmium, the trade records of osmium, iridium and ruthenium are made collectively. In 2013, worldwide 81 tons of osmium, iridium and ruthenium were exported, and 98 tons were imported. Exports were 74% from South Africa and 13% each from Germany and the United Kingdom [5]. Today, it can be assumed that the role of Germany has become less important, as German precious metal companies have shifted business from Germany directly to the producing countries.

Between 2010 and 2019, annual US imports of osmium ranged from less than 0.5 kg to 856 kg, averaging 157 kg per year [6]

Current annual production is expected to be between 150 kg [7] and 1000 kg [8].

Applications

The number of publications related to Osmium increased from 1,258 in the year 2000 to 2,421 in the year 2020 [9].

Historically, osmium was used alongside tungsten for filaments in light bulbs.

More recently, osmium has been used as an alloying component in fountain pens and phonographic needles, primarily because of its high hardness. Osmium-based catalysts are used in chemistry: The osmium-catalyzed cis-dihydroxylation of olefins is a unique process for the preparation of vicinal diols (Fig. 2, [10]).

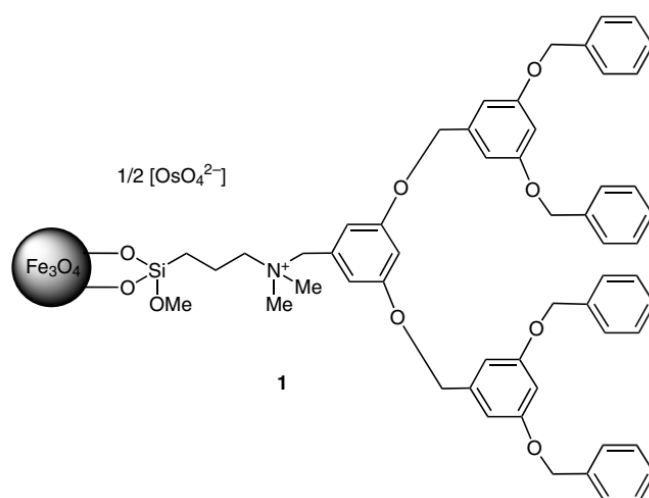


Fig. 2 Osmium catalyst for dihydroxylation [10]



Osmium is used in quantum spin liquids, which probably can be used for quantum computing. There the substance Osmium-Lithium-Oxide is forming a honeycomb-like lattice, used for magnetic frustration at a temperature of -273°C (Fig. 3, [11]).

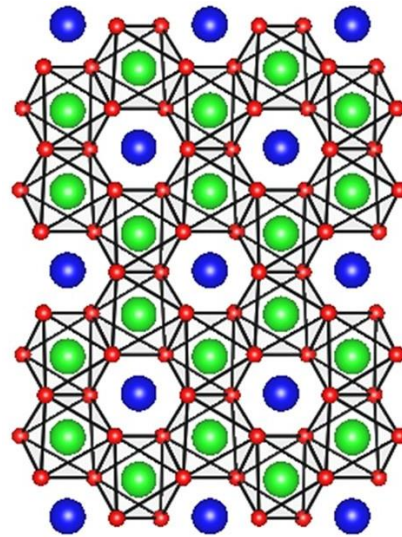


Fig. 3 Structure of $\text{Li}_{2.15}\text{Os}_{0.85}\text{O}_3$ Structure of (Li: blue, Os: green, O: red) [11]

The substance Osmium-Cadmium-Oxide is used in the research of massless particles, so called Weyl fermions. As these fermions can move much faster than electrons, faster electronic devices could be built in future (Fig. 4, [12]).

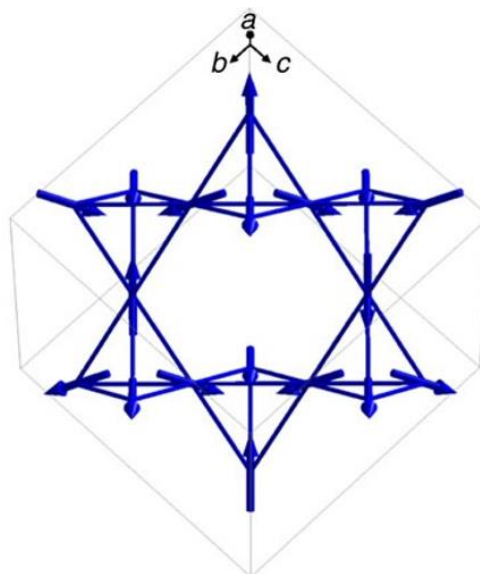


Fig. 4 Magnetic structure of $\text{Cd}_2\text{Os}_2\text{O}_7$ [12]

As Osmium is the most incompressible metal, it allows research under extreme pressure conditions with pressures above 7.5 million bar (750 Gigapascals, this corresponds to twice the pressure in the earth's core) without changing the internal structure [13].

In chemotherapy, 50% of the substances used are platinum-based, the so-called compounds cisplatin, carboplatin or oxaliplatin [14]. The platinum demand of the pharmaceutical industry is estimated at 2.5 - 3 tons per year [15]. The use of platinum-based chemotherapeutic agents has serious side effects. Initial studies show that these side effects do not occur with osmium- and ruthenium-based chemotherapeutic agents (Fig. 5, [16]).

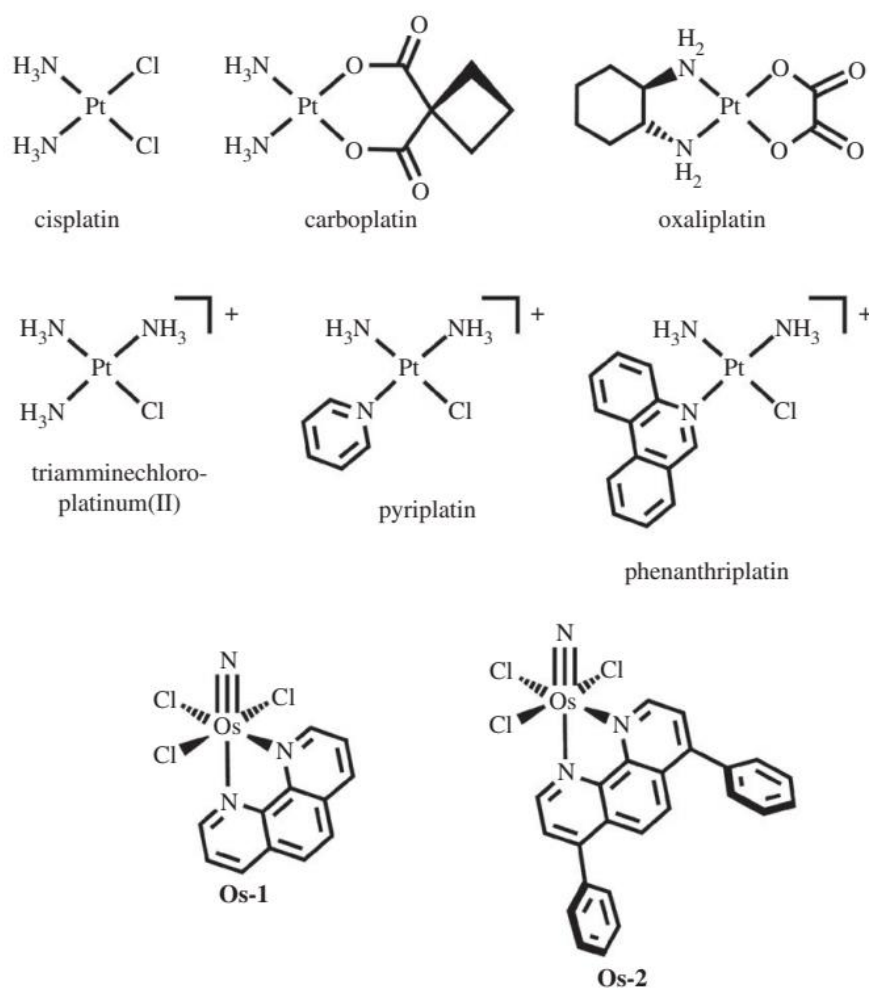


Fig. 5 Traditional, platinum based chemotherapy drugs (upper and middle row), osmium based chemotherapy drugs which are currently under development (lower row) [17]

Os(VI) compounds, like osmium nitride complexes, will allow cancers to be driven into remission and eliminate recurrence [17].

Recently, numerous other studies have appeared on this topic, making the use of osmium in the field of chemotherapeutics more likely (Fig. 6) [18, 19, 20]. The applicability of osmium in the field of photochemotherapy was also demonstrated. [21]

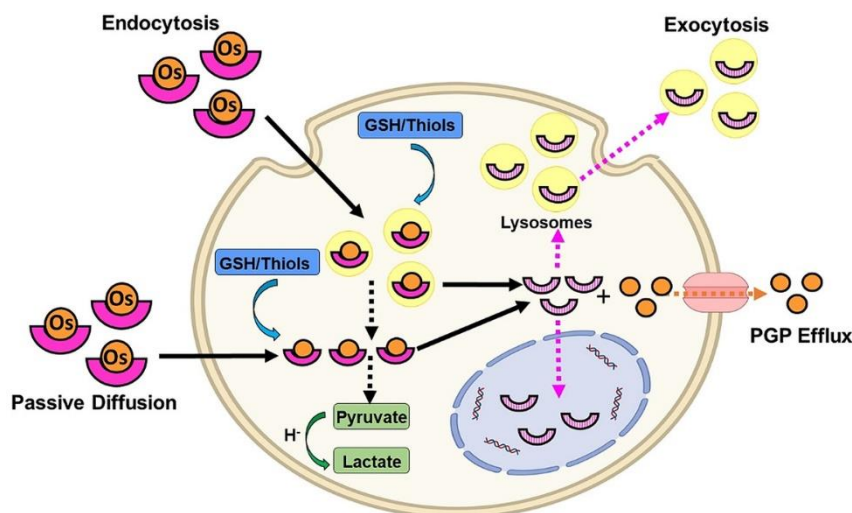


Fig. 6 Mechanisms for the uptake of Os containing chemotherapy drugs [18]

Price

Similar to gold, osmium also has a wide price range. For example, a 1g gold bar costs about 60 USD, and in processed form in the form of an elaborate ring, gold often costs several hundred USD per gram. The situation is similar for osmium: osmium powder with a purity of 99.9% cost about 12-18 USD per gram ex works in the summer of 2021 (Fig. 7). Osmium prices for Osmium powder/sponge were at \$350 from 1998 until June 2017. They then shot up to \$400 in June 2017, however remained constant at that level from 2017-2021 [22, 23].

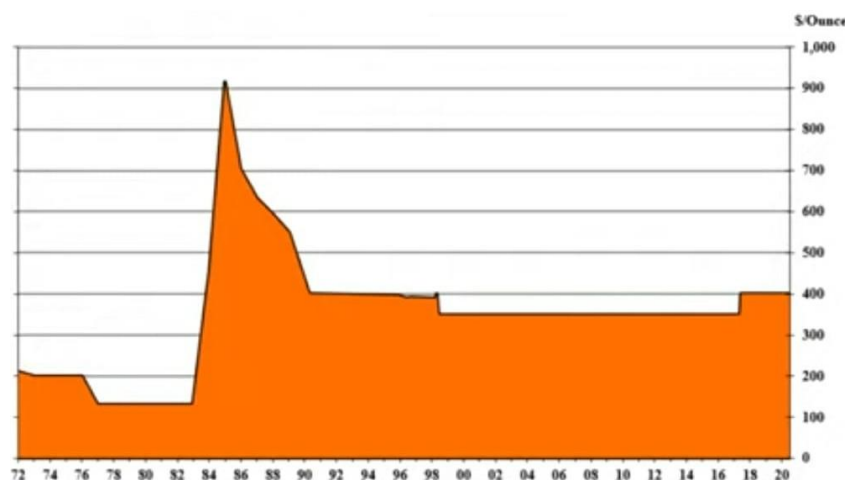


Fig. 7 Price for Osmium powder/sponge from 1972 until 2021 [23]



If this osmium powder is annealed in hydrogen to remove the last traces of the toxic oxide, the price increases by about 10%. By compacting/pressing this oxide-free osmium powder into cylinders for the melting process, the price increases by another 20%. Thus, pressed cylinders of osmium have production costs of about 25 USD. During the melting process in an electric arc furnace in an argon-helium atmosphere, in which a large proportion of the impurities evaporate, a further USD 10 in manufacturing costs per gram is incurred. After this melting process, osmium with a purity of over 99.97% is now available in the form of shiny beads with a manufacturing cost of roughly 35 USD. Shipping costs, customs duties, import taxes, value added tax, overhead surcharges and the dealer's commission result in a final selling price of about 50 USD per gram.

If these already high purity beads are now transformed into crystals with a purity of over 99.995% by chemical mass transfer at well over 1000°C, the price will increase further. Depending on the crystal size and yield, the production costs rise to 60-100 USD, resulting in a selling price of 80-120 USD.

Forecast

Economic uncertainty remains high with the pandemic still around and no exact timing insight when it will be fully over. This has, of course, effects on osmium like other industries, but the effects remain low in the long term. South Africa, the most important Osmium producer, is still having trouble with the pandemic, and some mines are not back at their pre-pandemic production levels yet. As the price for Osmium powder is fairly constant since 2017, we expect a moderate price increase in the short to middle term as prices for energy, workforce, etc. increased significantly since 2017. However, if Osmium will be used in quantum computers or chemotherapy drugs, the demand will be significantly higher than the supply (which cannot be adjusted in the short time due to the coupled production with other PGM), which can lead to a significant price increase in the middle to long-term.

Investment

With the other precious metals there is already for many years the possibility to simply invest in physical products (bars, coins) or financial products like mining shares or futures, options, ETF or a CFD.

In the case of osmium, until now there was only the possibility to invest in osmium powder, which you had to import yourself from the producers in South Africa, South America, Canada, Russia or China. Due to the always present content of osmium tetroxide, osmium powder cannot be stored safely. Since, on the other hand, compact osmium (beads and crystals) do not oxidize at room temperature, there is now the possibility to safely invest in physical osmium.



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