Osmium weighs in

Gregory Girolami recounts how element 76 beat a close competitor to the title of densest known metal and went on to participate in Nobel Prize-winning reactions.

The road to the title of heavyweight champion among the chemical elements began with the work of English chemist Smithson Tennant (1761–1815). Tennant obtained a medical degree, but after discovering that the sight of pain upset him too much, he abandoned the practice of medicine and decided to devote his life to chemistry[1,2]. He also developed some unconventional laboratory habits; for example, when a piece of linen was not available for a filtration, he often used his handkerchief or cut off a piece of his shirt.

In 1800, Tennant co-founded a business to sell platinum metal and began to prepare large quantities of it. He noticed, as had others before him, that extracting platinum out of its crude ores with aqua regia — a mixture of concentrated nitric and hydrochloric acids — left behind an insoluble black residue. In 1804, he announced his isolation of two new metals from the residue: iridium, named for "the striking variety of colours which it gives", and osmium, named after the Greek word for 'smell', *osme*, for the "pungent and peculiar smell of its oxide".

Osmium is the rarest of the stable elements: its average abundance in the Earth's crust is about 1 gram per 200 tonnes. Today, osmium is obtained commercially as a by-product of refining nickel and some of the more common platinum-group metals. The back seat of an automobile could easily accommodate the worldwide annual production of osmium — approximately 500 kilograms, which is about 5,000 times less than its gold counterpart.

Neighbours in the periodic table, osmium and iridium have long been known to be the densest of all metals (both are over twice as dense as lead), but which is the heavier of the two has been fiercely contested. Measuring their densities directly (by weighing samples of known volume) is not particularly accurate, owing in part to the difficulty of ensuring that the samples are free of internal voids. A better method involves a calculation based on their crystal structures and atomic weights but, because the densities are so similar, refinements in these measurements have occasionally resulted in the champion and challenger reversing positions.

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Osmium metal rivals diamond as the least compressible of all known substances.

Since its discovery, osmium has most often held the title of densest metal, but for many decades in the twentieth century it was iridium that occupied that position. More accurate studies carried out in the 1990s showed that osmium's density just slightly exceeds that of iridium[3]: the current values, 22.587 (Os) and 22.562 (Ir) g cm^{-3} at 20 °C differ by only 0.1%.

Despite its rarity, osmium is currently far less expensive than gold, partly because it has few commercial uses. Osmium metal — bluish-grey in colour, hard and brittle — lacks somewhat in visual and tactile appeal. But element 76 does have some redeeming qualities.

Osmium metal strongly resists being compressed under pressure, so much so that it rivals diamond as the least compressible of all known substances. Osmium can be mixed with other platinum-group elements to form alloys that, owing to their hardness, find speciality uses as electrical contacts, wear-resistant machine parts, and tips for high-priced ink pens. An urban legend is that osmium alloys are used in some surgical implants such as cardiac pacemakers and replacement heart valves, when in fact such alloys have never been used in these devices.

Although its metallic form has few applications, osmium's chemical behaviour is far from dull — it can exist in eleven different oxidation states, from –2 to +8; a versatility matched only by its chemical cousin ruthenium and a few other transition metals. Furthermore, the high +8 oxidation state reached by osmium — along with iron, ruthenium and xenon — is the highest seen for any chemical element under normal circumstances.

The most useful osmium compound is the tetroxide OsO_4, a colourless solid used as a stain in microscopy and in fingerprint detection. Osmium tetroxide is also used as a catalyst in a few commercial processes, such as the manufacture of certain anti-obesity and anti-diabetic drugs. These processes are based on the Nobel Prize-winning work of chemist K. Barry Sharpless, who used osmium tetroxide as a key component in a remarkable catalyst mixture that adds two hydroxyl (alcohol) groups to carbon–carbon double bonds[4].

So 'heavy as lead' turns out to be a rather half-hearted way to describe something that weighs a lot — but somehow I doubt that 'heavy as osmium' will ever catch on. ❐

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