Densities of Osmium and Iridium

RECALCULATIONS BASED UPON A REVIEW OF THE LATEST CRYSTALLOGRAPHIC DATA

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Much confusion exists in the literature concerning the densities of osmium and iridium. This has occurred because these values are calculated from crystallographic data, and errors in the absolute value of the X-ray wavelength scale, Avogadro's Number, and the atomic weights of these elements have only slowly been resolved. Unfortunately density values have been published from time to time which have incorporated one or more of these errors, and these have become fixed in the literature and repeated ever since.

The introduction of new values for Avogadro's Number and the X-ray wavelength scale conversion factor (1), both of which have been used in the present calculations, is an apt moment to review the crystallographic data for these elements and to show that osmium is the densest metal. Avogadro's Number is now $(6.0221367 \pm 0.0000036) \times 10^{23}$ per mol while the conversion factor from kX units to Ångström units is 1.00207789 ± 0.00000070. The equivalent Cu $K\alpha_1$ X-ray wavelength standard is then 1.5405945 ± 0.0000011 Å and an earlier version of this value (1.540598 Å) has already been adopted by the U.S. National Bureau of Standards (2) as a wavelength standard to replace the currently accepted conversion factor of 1.00202.

For iridium, which has a face-centred cubic structure, the density is calculated from:

$$\text{Density} = \frac{4 \times A_r}{N_A \times (a \times 10^{-8})^3}$$

where A_r = atomic weight
N_A = Avogadro's Number
a = lattice parameter in Ångström units

The atomic weight is well established at 192.22 ± 0.03 (3) while an average lattice parameter of 3.8392 ± 0.0005 Å at 20°C is selected from the high precision measurements given in Table I, which have been corrected to this temperature using a thermal expansion coefficient of 6.4×10^{-6} per °C (4). The calculated density is 22.562 ± 0.009 g/cm³ and the selected value is then 22.56 g/cm³ (22,560 kg/m³).

For osmium, which has a closer-packed hexagonal structure, the density is calculated from:

$$\text{Density} = \frac{2 \times A_r}{N_A \times \sin 60^\circ \times (a \times 10^{-8})^2 \times (c \times 10^{-8})}$$

where a and c = lattice parameters parallel to the a- and c-axes, respectively.

The accepted value for the atomic weight is 190.2 ± 0.1 (3), but this value is based entirely on the isotopic abundance measurements of Nier (10) and the actual value obtained is 190.238 ± 0.005 (11). Therefore 190.24 ± 0.10 has been used in calculating the density. Lattice parameters of a = 2.7343 ± 0.0005 Å and c = 4.3200 ± 0.0005 Å, at 20°C, have been selected from the measurements in Table II which have been corrected to this temperature using thermal expansion coefficients of 4.3×10^{-6} per °C parallel to the a-axis, and 6.8×10^{-6} per °C parallel to the c-axis (4).

The discrepant values of Owen, Pickup and Roberts, and Owen and Roberts may be associated with the relatively low purity of the metal used (99.8 per cent) while the measurements of Finkel', Palatnik and Kovtun, although apparently carried out on pure single crystals, nevertheless differ significantly from all other determinations on high purity materials. Hence these three values were rejected and the remainder were averaged to obtain the selected lattice parameters. A density of 22.588 ± 0.015 g/cm³ is then calculated;

Table I

Lattice Parameter of Iridium at 20°C

Literature reference	Value, Å	Temperature corrected from, °C
Owen and Yates (5)	3.8392	18
Swanson, Fuyat and Ugrinic (6)	3.8395	26
Schaake (7)	3.8397	25
Singh (8)	3.8390	30
Schröder, Schmitz-Pranghe and Kohlhaas (9)	3.8386	24

Table II

Lattice Parameters of Osmium, Parallel to the a- and c-axes, at 20°C, Ångström units

Literature reference	a	c	Temperature corrected from, °C
Owen, Pickup and Roberts (12)	2.7361	4.3190	18
Owen and Roberts (13)	2.7355	4.3194	20
Finkel', Palatnik and Kovtun (14)	2.7346	4.3174	20*
Swanson, Fuyat and Ugrinic (6)	2.7342	4.3198	26
Taylor, Doyle and Kagle (15)	2.7342	4.3201	23
Mueller and Heaton (16)	2.7346	4.3201	25
Schröder, Schmitz-Pranghe and Kohlhaas (9)	2.7340	4.3199	16

*Graphical only—actual values reported in Reference (4)

Table III

Crystallographic Data for the Platinum Group Metals, at 20°C

Element	Atomic number	Atomic weight (1985)	Structure	Lattice parameters		Nearest neighbour distance, nm	Density, kg/m³
				a, nm	c, nm		
Ruthenium	44	101.07	c.p.h.	0.27055	0.42816	0.26778	12,370
Rhodium	45	102.9055	f.c.c.	0.38034	–	0.26894	12,420
Palladium	46	106.42	f.c.c.	0.38902	–	0.27508	12,010
Osmium	76	190.2*	c.p.h.	0.27343	0.43200	0.27048	22,590
Iridium	77	192.22	f.c.c.	0.38392	–	0.27147	22,560
Platinum	78	195.08	f.c.c.	0.39235	–	0.27743	21,450

c.p.h. = close-packed hexagonal, f.c.c. = face-centred cubic

*Official value, 190.24 used in calculating the density (see text)

inclusion of all lattice parameters would lower this value by only 0.003 g/cm^3 however, and would therefore not affect the selected value of 22.59 g/cm^3 (22,590 kg/m^3) significantly.

Crystallographic data for the platinum group metals are presented in Table III. The lattice parameters for osmium and iridium are those selected above, while values for the remaining four platinum group metals are those selected by Donohue (17), after correction to the new conversion factor (1).

Having reviewed crystallographic data for both osmium and iridium, selected values of their densities at a temperature of 20°C are 22,590 kg/m^3 and 22,560 kg/m^3, respectively, thus confirming that osmium is the densest metal.

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Materials for Electronic Applications

Important applications for the platinum metals occur in the electronics industry. Present and future applications for these metals, and their related technology, have been considered here previously (1) as has the production of palladium powders for these applications by chemical precipitation techniques (2). With a continuing requirement for ever improved materials, a recent research summary of precipitation methods that have evolved from an investigation of solvent extraction-based techniques for the refining of noble metals is therefore timely (3).

Palladium powders were readily recovered from aqueous solutions by hydrogen reduction and examination by scanning electron microscopy showed the precipitate to consist generally of spherical particles. Those produced from a 1.0M hydrochloric acid solution displayed spikes upon the surface, but if the solution was less acidic, the number of spiked particles was considerably reduced.

Precipitation of palladium by hydrogen reduction from loaded organic extractants was slower than from the corresponding aqueous chloride system, and the particle size was significantly smaller. The surface of the spheres was smooth, but particle agglomeration could result from entrapment of aqueous phase media.

Platinum powders were produced by the hydrogen reduction of hydrogen hexachloroplatinate-hydrochloric acid-sodium chloride solutions. Precipitation rates were significantly slower than for palladium. Most of the platinum precipitated out as a black powder with a smooth, spherical appearance, the remainder forming platelets with a lustrous appearance. More uniform particles could be achieved by catalysing the reduction.

The morphology of the platinum particles could be changed by the addition of surface active molecules. Thus spheres could be eliminated, and flakes and platelets produced.

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