Calculating the Atomic Radius of Polonium

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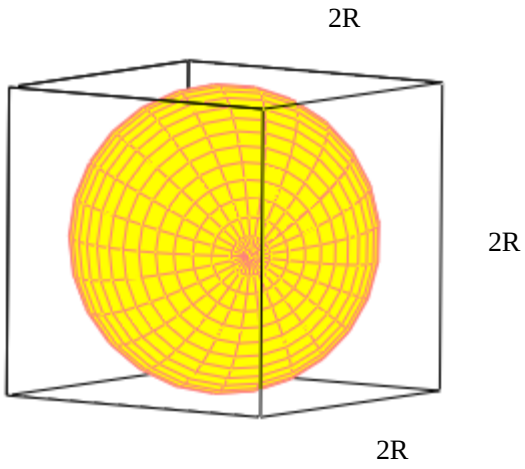
Three experimental facts are required to determine the atomic radius of a metallic element such as polonium: density, molar mass and crystal structure.

The crystal structure of room temperature polonium is simple cubic, the only metallic element in the periodic table with this structure. Its unit cell, or basic repeating unit, is shown below.



As noted above, this calculation will require, in addition to the crystal structure, the density and molar mass of polonium, which are given below along with Avogadro's number.

Density: $9.32 \cdot \frac{gm}{cm^3}$ Molar mass: $208.98 \cdot gm$ Atoms per mole: $6.022 \cdot 10^{23}$

Assuming that atomic polonium is a sphere, as shown above, we can calculate its atomic volume.

Atomic volume: $V_{atomic} = \frac{4}{3} \cdot \pi \cdot R^3$

However, as the unit cell (basic building block) shows, the effective volume of a polonium atom is a cube of side 2R. Therefore the effective volume of an atom of polonium is $8R^3$.

Effective atomic volume: $V_{effective} = (2 \cdot R)^3 \rightarrow V_{effective} = 8 \cdot R^3$

The next step involves calculating the packing efficiency of the simple cubic structure - in other words, the ratio of the atomic and effective volumes. We see that only 52.4% of the space is occupied by polonium atoms.

Ratio of atomic and effective volumes: $\frac{V_{atomic}}{V_{effective}} = \frac{\frac{4}{3} \cdot \pi \cdot R^3}{(2 \cdot R)^3}\ \text{float}, 3 \rightarrow \frac{V_{atomic}}{V_{effective}} = .524$

Next the reciprocal of the density, along with the molar mass and Avogadro's number is used to calculate the effective volume of an individual polonium atom.

Experimental effective volume: $V_{effective} := \frac{1 \cdot cm^3}{9.32 \cdot gm} \cdot \frac{208.98 \cdot gm}{6.022 \cdot 10^{23}}$ $V_{effective} = 3.723 \times 10^{-23}\, cm^3$

The atomic volume is 52.4% of the effective volume.

$$V_{atomic} = 0.524 \cdot V_{effective} \text{ float}, 3 \rightarrow V_{atomic} = .195\text{e-}22 \cdot cm^3$$

This allows the calculation of the atomic radius of polonium.

$$\frac{4}{3} \cdot \pi \cdot R^3 = 0.524 \cdot V_{effective} \qquad R := \left(\frac{0.524 \cdot V_{effective}}{\frac{4}{3} \cdot \pi} \right)^{\frac{1}{3}} \qquad R = 167\, pm$$

This is in agreement with the literature value (see Figure 5.19 page 176 in *Chemistry*, 5th edition, by McMurry and Fay).

Define picometer: $pm \equiv 10^{-12} \cdot m$