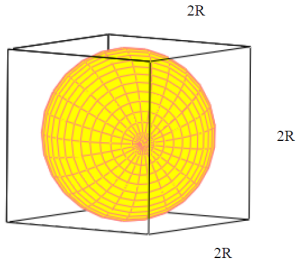
2.46: Calculating the Atomic Radius of Polonium

Three experimental facts are required to determine the atomic radius of a metallic element such as polonium:

1. density,
2. molar mass and
3. 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: $\rho = 9.32\ g/cm^3$
- Molar Mass (MM): $208.98\ g/mol$
- Atoms per mole: $N_a = 6.023 \times 10^{23}$

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

Atomic volume

$$V_{atomic} = \frac{4}{3}\pi R^3 \tag{2.46.1}$$

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 R^3.

Effective atomic volume

$$V_{effective} = (2R)^3 = 8R^3 \tag{2.46.2}$$

The next step involves calculating the packing efficiency of the simple cubic structure - in other words, the ratio of the atomic and effective volumes.

Ratio of atomic and effective volumes

$$\frac{V_{atomic}}{V_{effective}} = \frac{\frac{4}{3}\pi R^3}{8R^3} \tag{2.46.3}$$

$$= 0.524 \tag{2.46.4}$$

We see that only 52.4% of the space is occupied by polonium atoms. 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

$$V_{effective} = \left(\frac{1}{\rho}\right)\left(\frac{MM}{N_a}\right)$$
$$= \left(\frac{1}{9.32\ \cancel{g}/cm^3}\right)\left(\frac{208.98\ \cancel{g}/\ \cancel{mol}}{6.02210^{23}\ atoms/\ \cancel{mol}}\right)$$
$$= 3.723 \times 10^{23}\ cm^3/atom$$

The atomic volume is 52.4% of the effective volume.

$$V_{atomic} = 0.524 V_{effective} = 0.195 \times 10^{-22} cm^3 \tag{2.46.5}$$

This allows the calculation of the atomic radius of polonium.

$$\frac{4}{3}\pi R^3 = 0.524\ V_{effective}$$
$$R = \left(\frac{0.524\ V_{effective}}{\frac{4}{3}\pi}\right)^{\frac{1}{3}}$$
$$= 167 \times 10^{12}\ m = 167\ pm$$

This is in agreement with the literature value.

Contributors and Attributions

- Prof. Emeritus Frank Rioux (St. John's University and College of St. Benedict)