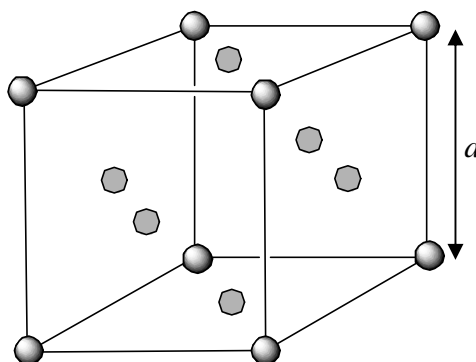


**Marks**  
**5**

- The diagram below shows the structure of an alloy of copper and gold with a gold atom at each of the corners and a copper atom in the centre of each of the faces. The unit cell dimension (edge length,  $a$ ) for this alloy is 0.36 nm.



What is the chemical formula of the alloy?

**There are 8 Au atoms on the corners. Each of these contribute 1/8 to the unit cell:**

$$\text{number of Au atoms} = 8 \times 1/8 = 1$$

**There are 6 Cu atoms on the face. Each of these contribute 1/2 to the unit cell:**

$$\text{number of Cu atoms} = 6 \times 1/2 = 3$$

**The ratio of Cu to Au atoms is therefore 3 : 1 and the formula is Cu<sub>3</sub>Au.**

Answer: **Cu<sub>3</sub>Au**

Given that pure gold is 24 carat and gold alloyed with 25% by weight of another metal is termed 18 carat gold, what carat gold is this alloy?

**The molar mass of Cu<sub>3</sub>Au is:**

$$\text{molar mass} = (3 \times 63.55 \text{ (Cu)} + 1 \times 196.97 \text{ (Au)}) \text{ g mol}^{-1} = 387.62 \text{ g mol}^{-1}.$$

**As 1 mol of Cu<sub>3</sub>Au contains 1 mol of Au, the percentage by weight of gold in Cu<sub>3</sub>Au is:**

$$\text{percentage by weight} = \frac{197.67}{387.62} \times 100 \% = 50 \%$$

**As a 100 % alloy is 24 carat and a 75% alloy is 18 carat, a 50 % alloy is 12 carat.**

Answer: **12 carat**

What is the volume of the unit cell?

**As the unit cell is cubic:**

$$\text{volume} = (\text{side length})^3 = a^3 = (0.36 \times 10^{-9} \text{ m})^3 = 4.7 \times 10^{-29} \text{ m}^3$$

Answer:  **$4.7 \times 10^{-29} \text{ m}^3$**

**ANSWER CONTINUES ON THE NEXT PAGE**

What is the density of the alloy?

**From above, the unit cell contains 1 Au atom and 3 Cu atoms:**

$$\text{mass of gold} = 196.97 \text{ g mol}^{-1} / 6.022 \times 10^{23} \text{ mol}^{-1} = 3.271 \times 10^{-22} \text{ g}$$

$$\text{mass of copper} = 3 \times 63.55 \text{ g mol}^{-1} / 6.022 \times 10^{23} \text{ mol}^{-1} = 3.166 \times 10^{-22} \text{ g}$$

$$\text{mass of unit cell} = (3.271 \times 10^{-22} + 3.166 \times 10^{-22}) \text{ g} = 6.437 \times 10^{-22} \text{ g}$$

**The density is therefore:**

$$\text{density} = \text{mass} / \text{volume}$$

$$= 6.437 \times 10^{-22} \text{ g} / 4.7 \times 10^{-29} \text{ m}^3 = 1.4 \times 10^7 \text{ g m}^{-3}$$

**As 1 m = 100 cm, 1 m<sup>3</sup> = (100)<sup>3</sup> cm<sup>3</sup> = 10<sup>5</sup> cm<sup>3</sup>:**

$$\text{density} = 14 \text{ g cm}^{-3}$$

**Answer: 14 g cm<sup>-3</sup>**