A Pure Copper Cube Has An Edge Length Of 3.00 CmHow Many Copper Atoms Does It Contain? (volume Of A Cube

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Understanding the microscopic world of atoms and molecules allows us to appreciate the immense scale and the intricate details of everyday objects. One fascinating question in the realm of chemistry and physics is: How many atoms are contained in a solid object of a given size? Specifically, consider a pure copper cube with an edge length of 3.00 cm. How many copper atoms does it contain? To answer this, we need to explore concepts such as the volume of the cube, the atomic structure of copper, molar mass, and Avogadro's number. This article provides a comprehensive explanation, guiding you step-by-step through the calculations involved.

Understanding the Problem

Before delving into calculations, it’s essential to understand the key concepts involved:

- Volume of the cube: Determines the total space occupied by the copper.
- Density of copper: Relates mass and volume.
- Molar mass of copper: The mass of one mole of copper atoms.
- Avogadro's number: The number of atoms or molecules in one mole of substance.

By utilizing these concepts, we can find the total number of atoms within the cube.

Step 1: Calculating the Volume of the Copper Cube

The volume (V) of a cube with edge length (a) is given by:

$$
V = a^3
$$

Given:

$$
a = 3.00\, \text{cm}
$$

Calculating:

$$
V = (3.00\, \text{cm})^3 = 27.00\, \text{cm}^3
$$

Thus, the volume of the copper cube is 27.00 cubic centimeters.

Step 2: Understanding Copper’s Physical Properties

To proceed, we need to consider some physical properties of copper:

- Density of copper (ρ): approximately 8.96 g/cm³
- Atomic mass of copper (Cu): approximately 63.55 g/mol
- Avogadro's number (N_A): 6.022×10^{23} atoms/mol

These properties are crucial for converting volume into mass and then into the number of atoms.

Step 3: Calculating the Mass of the Copper Cube

Using the density formula:

$$
\text{Mass} = \text{Density} \times \text{Volume}
$$

Substituting known values:

$$
\text{Mass} = 8.96\, \text{g/cm}^3 \times 27.00\, \text{cm}^3 = 242.0\, \text{g}
$$

The mass of the copper cube is approximately 242.0 grams.

Step 4: Calculating the Number of Moles of Copper

The number of moles in a given mass is calculated by:

$$
\text{Number of moles} = \frac{\text{Mass}}{\text{Molar mass}}
$$

Substituting the known values:

$$
\text{Number of moles} = \frac{242.0\, \text{g}}{63.55\, \text{g/mol}} \approx 3.81\, \text{mol}
$$

So, the cube contains approximately 3.81 moles of copper atoms.

Step 5: Calculating the Total Number of Copper Atoms

Using Avogadro’s number, the total number of atoms is:

$$
\text{Total atoms} = \text{Number of moles} \times N_A
$$

Calculating:

$$
\text{Total atoms} = 3.81\, \text{mol} \times 6.022 \times 10^{23}\, \text{atoms/mol} \approx 2.29 \times 10^{24}\, \text{atoms}
$$

Therefore, the copper cube contains approximately 2.29 x 10^24 copper atoms.

Summary of the Calculation Process

Here's a quick overview of the steps involved:

1. Calculate the volume of the cube using $V = a^3$.

2. Determine the mass of the copper using its density: $\text{Mass} = \text{Density} \times V$.

3. Find the number of moles by dividing mass by molar mass: $\text{moles} = \frac{\text{Mass}}{\text{Molar mass}}$.

4. Compute the total number of atoms using Avogadro's number: $\text{Atoms} = \text{moles} \times N_A$.

Additional Considerations and Real-World Applications

Understanding how many atoms are contained in a macroscopic object like a copper cube has practical applications, including:

- Material Science: Estimating atomic-scale properties based on macroscopic measurements.
- Chemistry Education: Demonstrating the relationship between microscopic particles and macroscopic properties.
- Nanotechnology: Designing materials at the atomic level for specific functions.
- Metallurgy: Understanding the atomic structure to manipulate physical properties.

Knowing the atomic count also helps in understanding concepts like atomic packing factor, crystalline structure, and how defects at the atomic level affect material properties.

Conclusion

Calculating the number of atoms in a copper cube with an edge length of 3.00 cm involves understanding and applying basic principles of volume, density, molar mass, and Avogadro's number. The process demonstrates the fascinating connection between the macroscopic world we can see and measure, and the microscopic realm of atoms and molecules. This calculation reveals that a relatively small cube of copper contains on the order of 2.29 x 10^24 atoms, highlighting the incredible density of atomic matter and the scale at which the universe operates.

Additional Resources for Further Learning

- Chemistry Textbooks: For detailed explanations of molar concepts and atomic structures.
- Material Science Courses: To understand the physical properties of metals.
- Online Calculators: For quick volume, mass, and molar calculations.
- Research Articles: Exploring atomic-scale modeling of materials.

By mastering these calculations, students and professionals can better understand material properties, perform accurate measurements, and design advanced materials for future technologies.

Note: All calculations are approximate and based on standard physical constants and properties. Actual values may vary slightly depending on purity and measurement conditions.

Frequently Asked Questions

What is the volume of a pure copper cube with an edge length of 3.00 cm?

The volume is calculated by cubing the edge length: V = 3.00 cm × 3.00 cm × 3.00 cm = 27.00 cm^3.

How do you determine the number of copper atoms in the cube?

First, find the mass of the cube using its volume and the density of copper, then convert that mass to moles using molar mass, and finally multiply by Avogadro's number to find the number of atoms.

What is the density of copper used in calculations?

The density of copper is approximately 8.96 g/cm^3.

What is the molar mass of copper?

The molar mass of copper (Cu) is approximately 63.55 g/mol.

How many copper atoms are in the cube with edge length 3.00 cm?

Using the calculations: mass = volume × density = 27.00 cm^3 × 8.96 g/cm^3 ≈ 241.92 g; moles = mass / molar mass ≈ 241.92 g / 63.55 g/mol ≈ 3.81 mol; atoms = moles ×

Avogadro's number (6.022×10^{23}) ≈ 2.29×10^{24} atoms.

What is the significance of Avogadro's number in this calculation?

Avogadro's number (6.022×10^{23}) represents the number of atoms in one mole of a substance, allowing us to convert moles to individual atoms.

Can this method be used to find the number of atoms in any cube of a different material?

Yes, by adjusting the density and molar mass values specific to the material, the same method applies to any cube.

Why is understanding the volume of the cube important in this calculation?

The volume allows us to determine the mass of the copper cube, which is essential for calculating the number of atoms contained within it.

Additional Resources

A Pure Copper Cube Has An Edge Length Of 3.00 Cm How Many Copper Atoms Does It Contain? (Volume Of A Cube)

Understanding the microscopic world often begins with simple, tangible objects. When we consider a pure copper cube with an edge length of 3.00 cm, one of the fascinating questions that arise is: How many copper atoms does it contain? This question bridges the macroscopic measurements of everyday objects with the tiny, atomic scale, offering insight into the fundamental building blocks of matter. In this comprehensive guide, we will delve into the step-by-step process of calculating the number of atoms in such a copper cube, exploring concepts from volume calculations and molar quantities to atomic structure and density.

The Significance of Volume in Atomic Calculations

The volume of an object is a critical starting point when transitioning from macroscopic measurements to atomic-scale quantities. For a cube, calculating its volume is straightforward: since the volume of a cube equals the cube of its edge length, the key lies in converting this volume into the number of atoms, considering the material's atomic properties.

Step 1: Calculating the Volume of the Copper Cube

Given the edge length of the cube:

- Edge length (a): 3.00 cm

The volume (V) of a cube is:

$$ V = a^3 $$

Substituting the given value:

$$ V = (3.00\, \text{cm})^3 = 27.00\, \text{cm}^3 $$

This is the total volume of the copper cube.

Step 2: Understanding Copper's Density and Molar Mass

To relate the physical volume to the number of atoms, we need two key pieces of information about copper:

- Density (ρ): The mass per unit volume of copper.
- Molar mass (M): The mass of one mole of copper atoms.

Copper's Density:

Copper has a density of approximately:

$$ \boxed{8.96\, \text{g/cm}^3} $$

Copper's Molar Mass:

The molar mass of copper (Cu):

$$ \boxed{63.55\, \text{g/mol}} $$

Step 3: Calculating the Mass of the Copper Cube

Using the density, the mass (m) of the cube can be found by:

$$ m = \rho \times V $$

Substituting the values:

$$ m = 8.96\, \text{g/cm}^3 \times 27.00\, \text{cm}^3 = 241.92\, \text{g} $$

So, the copper cube weighs approximately 241.92 grams.

Step 4: Determining the Number of Moles of Copper

One mole of copper contains approximately 6.022×10^{23} atoms (Avogadro's number). The number of moles (n) in the cube can be calculated as:

$$ n = \frac{m}{M} $$

Substituting the known values:

$$ n = \frac{241.92\, \text{g}}{63.55\, \text{g/mol}} \approx 3.81\, \text{mol} $$

Thus, the cube contains approximately 3.81 moles of copper atoms.

Step 5: Calculating the Number of Atoms

To find the total atoms (N):

$$ N = n \times N_A $$

where:

- N_A = Avogadro's number $\approx 6.022 \times 10^{23} \, \text{atoms/mol}$

Calculating:

$$ N = 3.81\, \text{mol} \times 6.022 \times 10^{23}\, \text{atoms/mol} $$

$$ N \approx 2.29 \times 10^{24} \text{ atoms} $$

Summary of the Calculation

Step	Calculation	Result
Volume of cube	$(3.00\, \text{cm})^3$	27.00 cm³
Mass of cube	$8.96\, \text{g/cm}^3 \times 27.00\, \text{cm}^3$	241.92 g
Moles of copper	$241.92\, \text{g} / 63.55\, \text{g/mol}$	3.81 mol
Number of atoms	$3.81 \times 6.022 \times 10^{23}$	$\approx 2.29 \times 10^{24}$ atoms

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Additional Insights and Considerations

Atomic Structure of Copper:
Copper crystallizes in a face-centered cubic (FCC) structure, which influences how atoms are packed within the material. Though this doesn't affect the count of atoms in the entire cube, understanding the atomic packing factor (APF) can be insightful for advanced

material science studies.

Real-World Variations:
- Purity: Real copper may contain impurities, slightly affecting density.
- Temperature: Density varies with temperature; the above calculation assumes room temperature.
- Measurement Accuracy: Precision in measuring edge length impacts the final atom count.

Conclusion

Determining how many copper atoms are contained within a pure copper cube with an edge length of 3.00 cm involves translating macroscopic measurements into atomic quantities through a series of logical steps. Starting with calculating the volume and mass, then progressing to moles and finally to the number of atoms, this process illustrates the profound connection between everyday objects and the microscopic world of atoms. Such calculations are foundational in fields ranging from materials science to nanotechnology, where understanding the atomic composition of materials underpins innovation and discovery.

Summary of Key Formulas

- Volume of cube: $V = a^3$
- Mass of object: $m = \rho \times V$
- Number of moles: $n = \frac{m}{M}$
- Number of atoms: $N = n \times N_A$

By mastering these fundamental steps, you can approach a wide array of questions involving atomic counts in various materials and geometries, opening doors to deeper understanding in the physical sciences.

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