

A 10.0 Cm³ Sample Of Copper Has A Mass Of 90 G. What Is The Density Of Copper?

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Understanding the concept of density is fundamental in the fields of physics, chemistry, and material science. When analyzing materials such as copper, calculating density helps determine whether a sample is pure, identify potential impurities, and compare it with standard values. In this article, we will explore how to calculate the density of a copper sample given its volume and mass, delve into the significance of density in scientific contexts, and provide comprehensive insights into the properties of copper as a material.

What Is Density? An Overview

Definition of Density

Density is a physical property that describes how much mass is contained within a given volume of a substance. It is a measure of how tightly matter is packed together in a material. Mathematically, density (denoted as ρ) is expressed as:

$$\rho = \frac{\text{Mass}}{\text{Volume}}$$

where:

- Mass is typically measured in grams (g) or kilograms (kg).
- Volume is measured in cubic centimeters (cm³), liters (L), or cubic meters (m³).

The SI (International System of Units) unit for density is kilograms per cubic meter (kg/m³), but in everyday applications, grams per cubic centimeter (g/cm³) or grams per milliliter (g/mL) are commonly used.

Importance of Density in Science and Industry

- Material Identification: Density helps identify unknown substances by comparing measured values with standard data.

- Quality Control: Ensures the purity and consistency of materials in manufacturing processes.
- Design and Engineering: Critical in designing objects where weight and strength are factors.
- Buoyancy and Archimedes' Principle: Determines whether objects float or sink in fluids based on their density relative to the fluid.

Calculating the Density of Copper

Given Data

For our specific case, the data provided are:

- Volume (V): 10.0 cm³
- Mass (m): 90 g

Our goal is to calculate the density (ρ) of this copper sample.

Step-by-Step Calculation

Using the formula:

$$\rho = \frac{m}{V}$$

Substitute the known values:

$$\rho = \frac{90 \text{ g}}{10.0 \text{ cm}^3}$$

Perform the division:

$$\rho = 9.0 \text{ g/cm}^3$$

Result:

The density of the copper sample is 9.0 g/cm³.

Understanding the Result: Is It Consistent with Standard Copper Density?

Standard Density of Copper

Copper is a well-studied metal with a standard density of approximately 8.96 g/cm^3 at room temperature. This value serves as a benchmark for identifying purity and assessing the quality of copper samples.

Comparison and Analysis

- The calculated density of 9.0 g/cm^3 is very close to the standard value of copper.
- Minor discrepancies can arise due to measurement errors, impurities, or temperature variations.
- The small difference (about 0.04 g/cm^3) suggests the sample is quite pure and standard in composition.

Implications

- The close match affirms that the sample is consistent with pure copper.
- Slight deviations are typical in experimental measurements and can be minimized with precise tools and techniques.

Factors Affecting the Density of Copper

Temperature

- Copper expands when heated, slightly decreasing its density.
- Conversely, cooling copper causes contraction, increasing its density.
- Densities are often specified at standard room temperature (around 20°C).

Impurities and Alloying

- The presence of other metals or impurities can alter the density.
- Copper alloys, such as bronze and brass, have different densities compared to pure copper.

Measurement Accuracy

- Precision in measuring mass and volume directly affects the calculated density.
- Using calibrated instruments minimizes errors.

Practical Applications of Copper Density Measurement

Material Quality Assessment

- Ensuring a copper sample's density aligns with standard values confirms purity.
- Detects contamination or alloying that may compromise performance.

Manufacturing and Engineering

- Accurate density data supports designing components requiring specific weight-to-strength ratios.
- Used in calculations for casting, machining, and fabrication processes.

Scientific Research

- Helps in studying physical properties, phase transitions, and thermal expansion.
- Essential in research involving copper's electrical and thermal conductivities.

Additional Methods to Determine Density

Archimedes' Principle

- Submerging the sample in water or another fluid to measure displaced volume.
- Useful when direct volume measurement is challenging.

Pycnometry

- Using a pycnometer to measure the volume based on fluid displacement.
- Offers high precision for small samples.

X-ray Computed Tomography (CT)

- Advanced imaging technique to determine internal structure and volume.
- Suitable for complex shapes or porous materials.

Summary and Key Takeaways

- The density of a copper sample with a volume of 10.0 cm³ and a mass of 90 g is approximately 9.0 g/cm³.
- This value aligns closely with the standard density of pure copper at room temperature.
- Accurate measurement of mass and volume is essential for precise density calculation.
- Density is a vital property for material identification, quality control, and engineering applications.
- Variations in density can result from temperature changes, impurities, or measurement errors.

Conclusion

Understanding how to calculate and interpret the density of copper is crucial for students, scientists, and engineers. By applying the fundamental formula $\rho = \frac{m}{V}$, one can effectively determine the density of any material given its mass and volume. The example of a 10.0 cm³ copper sample with a mass of 90 g demonstrates how closely measured densities can match standard values, reinforcing the importance of precision in scientific measurements. Whether used for material verification, quality assurance, or research, density remains a cornerstone property in the study and application of materials like copper.

FAQs

Q1: Why is the density of copper important?

A1: It helps identify purity, assess material quality, and is essential in engineering

applications where weight and strength are critical.

Q2: Can the density of copper vary?

A2: Yes, due to temperature, impurities, alloying, and measurement methods.

Q3: How can I improve the accuracy of density measurements?

A3: Use calibrated instruments, perform measurements at controlled temperatures, and repeat measurements to average out errors.

Q4: Is density the same at all temperatures?

A4: No, density varies with temperature; materials generally expand when heated, decreasing density.

Q5: What are other methods to measure density besides direct calculation?

A5: Archimedes' principle, pycnometry, and advanced imaging techniques like CT scans.

By mastering the principles of density calculation and understanding its significance, you can better analyze materials like copper and apply this knowledge across scientific and engineering disciplines.

Frequently Asked Questions

What is the formula to calculate the density of a substance?

Density is calculated as mass divided by volume, expressed as $\text{Density} = \text{Mass} / \text{Volume}$.

Given a 10.0 cm³ sample of copper with a mass of 90 g, how do you find its density?

Divide the mass (90 g) by the volume (10.0 cm³): $\text{Density} = 90 \text{ g} / 10.0 \text{ cm}^3 = 9.0 \text{ g/cm}^3$.

Is the density of copper typically around 8.96 g/cm³ or 9.0 g/cm³?

The standard density of copper is approximately 8.96 g/cm³, so with the given data, the calculated density is close but slightly higher due to measurement variations.

Why is knowing the density of copper important in practical applications?

Density helps determine material purity, weight, and suitability for specific uses such as electrical wiring, plumbing, and manufacturing.

How does the density of copper compare to other metals?

Copper's density ($\sim 8.96 \text{ g/cm}^3$) is less than metals like gold ($\sim 19.32 \text{ g/cm}^3$) and silver ($\sim 10.49 \text{ g/cm}^3$), but higher than aluminum ($\sim 2.70 \text{ g/cm}^3$).

What are common units used for expressing the density of metals like copper?

Density is typically expressed in grams per cubic centimeter (g/cm^3) or kilograms per cubic meter (kg/m^3).

If the measured density of copper is higher than the standard value, what could be the reason?

Possible reasons include impurities in the sample, measurement errors, or the presence of alloying elements increasing the overall density.

Can the density of copper vary with temperature? Why?

Yes, the density of copper decreases slightly with increasing temperature due to thermal expansion, which increases volume while mass remains constant.

Additional Resources

Density of Copper: An In-Depth Analysis of a 10.0 cm^3 Sample with a Mass of 90 g

Understanding the physical properties of materials is fundamental in both scientific research and practical applications. Among these properties, density plays a critical role in identifying substances, calculating their behavior under different conditions, and understanding their structural characteristics. In this article, we explore the density of copper, focusing on a specific case where a sample measures 10.0 cm^3 in volume and weighs 90 grams. This detailed examination will not only provide the numerical answer but also delve into the concepts, methods, and implications surrounding the calculation of density, especially in the context of metals like copper.

Introduction to Density: Definition and Significance

What is Density?

Density is a fundamental physical property defined as the mass of a substance per unit volume. Mathematically, it is expressed as:

$$\rho = \frac{m}{V}$$

where:

- ρ represents density, typically in units such as grams per cubic centimeter (g/cm^3) or kilograms per cubic meter (kg/m^3).
- m is the mass of the object or sample.
- V is the volume it occupies.

This property provides insight into how tightly matter is packed within a given space. Materials with high density, such as metals, are characterized by closely packed atoms, whereas materials with low density, like gases or porous substances, have more space between their particles.

Why is Density Important?

Density has several practical and scientific implications:

- **Material Identification:** Each material has a characteristic density, allowing for identification or verification of material purity.
- **Engineering and Design:** Knowledge of density influences design decisions, especially in weight-sensitive applications such as aerospace, automotive, and construction.
- **Buoyancy and Fluid Dynamics:** Density differences determine whether objects sink or float, essential in shipbuilding and fluid mechanics.
- **Material Properties and Behavior:** Density correlates with other properties like strength, thermal conductivity, and electrical conductivity.

In metallurgy, particularly in the study of metals like copper, density helps understand the material's crystalline structure, purity, and manufacturing quality.

Calculating the Density of Copper: A Step-by-Step Approach

Given Data

- Volume of copper sample, $V = 10.0 \text{ cm}^3$
- Mass of copper sample, $m = 90 \text{ g}$

Step 1: Recall the Density Formula

The fundamental formula for density is:

$$\rho = \frac{m}{V}$$

Step 2: Substitute the Known Values

Plugging in the given data:

$$\rho = \frac{90 \text{ g}}{10.0 \text{ cm}^3}$$

Step 3: Perform the Calculation

Dividing:

$$\rho = 9 \text{ g/cm}^3$$

Result:

The density of the copper sample is 9 g/cm³.

Contextualizing the Result: How Does Copper's Density Compare?

Standard Density of Copper

The accepted standard density of pure copper at room temperature (~20°C) is approximately 8.96 g/cm³. Our calculated value of 9 g/cm³ closely aligns with this, indicating:

- The sample is likely of high purity.
- The measurement and calculation are accurate within typical experimental error margins.

Implications of the Slight Difference

A minor discrepancy (0.04 g/cm³) could arise from:

- Measurement inaccuracies, especially in volume or mass.

- Slight impurities or alloying elements in the sample.
- Temperature variations affecting density measurements.

Such differences are common in practical scenarios and highlight the importance of precise measurement techniques.

Understanding Copper's Physical Properties in Depth

Crystalline Structure and Density

Copper, a transition metal, crystallizes in a face-centered cubic (FCC) structure. This arrangement of atoms influences its density, mechanical strength, electrical properties, and thermal conductivity. The FCC structure allows a high packing efficiency (~74%), meaning a significant portion of the volume is occupied by atoms.

The atomic weight of copper is approximately 63.55 g/mol, and its atomic radius is about 128 pm (picometers). The relationship between atomic structure and density involves the number of atoms per unit cell and the volume of the unit cell.

Calculating Theoretical Density of Copper

Using the lattice parameters:

$$\rho_{\text{theoretical}} = \frac{Z \times M}{N_A \times a^3}$$

where:

- Z is the number of atoms per unit cell (for FCC, $Z=4$),
- M is molar mass (~63.55 g/mol),
- N_A is Avogadro's number ($\sim 6.022 \times 10^{23} \text{ mol}^{-1}$),
- a is the lattice parameter (~0.3615 nm).

Plugging in the values:

$$\rho_{\text{theoretical}} \approx 8.96 \text{ g/cm}^3$$

which confirms the experimentally obtained density aligns with theoretical expectations.

Applications and Significance of Copper's Density

Industrial Applications

Copper's high density and excellent electrical and thermal conductivity make it invaluable:

- Electrical Wiring: Heavy weight necessitates careful handling, but high conductivity offers efficiency.
- Plumbing: Dense and corrosion-resistant, ideal for pipes and fittings.
- Alloys: Alloys like bronze and brass leverage copper's properties, with density influencing their strength and weight.

Scientific and Engineering Considerations

- Material Selection: Engineers select copper based on its density for weight calculations and structural design.
- Quality Control: Variations in density can indicate impurities or manufacturing defects. Precise density measurements serve as quality assurance tools.
- Research: Understanding copper's density aids in studying its behavior under different environmental conditions, such as high pressure or temperature.

Conclusion: The Significance of Accurate Density Determination

The calculation of the density of copper, as demonstrated with a 10.0 cm³, 90 g sample, exemplifies how fundamental principles of physics can be applied to real-world materials. The close agreement between the calculated density (9 g/cm³) and the standard value (~8.96 g/cm³) underscores the reliability of straightforward measurement and calculation techniques in material science.

Accurate density measurements are more than mere numerical exercises; they are vital tools in material identification, quality control, and engineering design. Understanding the density of copper not only offers insights into its atomic structure and purity but also influences its application across diverse industries. As materials science advances, precise characterization of fundamental properties like density remains essential in pushing the boundaries of technology and innovation.

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Author's Note:

This comprehensive analysis aims to elucidate the concept of density through practical calculation and contextual understanding, fostering a deeper appreciation of this fundamental property in materials science.

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