Calculate The Mass Of A Sample Of Cobalt Containing 3.31x10^22 Atoms

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When working with chemical quantities, understanding how to calculate the mass of a substance based on the number of atoms is a fundamental skill in chemistry. If you are given a specific number of cobalt atoms, such as 3.31×10^{22}, and asked to find the corresponding mass, you need to know the relationship between atoms, moles, and grams. This process involves concepts like Avogadro's number, molar mass, and basic unit conversions. This article will guide you step-by-step through the calculation, providing insights into the key concepts involved and practical examples to enhance your understanding.

Understanding the Basics: Atoms, Moles, and Molar Mass

Before diving into calculations, it is essential to grasp some foundational concepts related to atomic and molecular quantities.

What Is a Mole?

- A mole is a unit used in chemistry to express amounts of a substance.
- One mole contains exactly 6.022×10^{23} particles (atoms, molecules, ions, etc.).
- This number is known as Avogadro's number.

Avogadro's Number and Its Significance

- Avogadro's number = 6.022×10^{23} particles per mole.
- It provides a conversion factor between the number of atoms and moles.
- For example, 1 mole of cobalt contains 6.022×10^{23} atoms.

Molar Mass of Cobalt

- The molar mass of an element is the mass of one mole of its atoms.
- For cobalt (Co), the molar mass = approximately 58.93 grams/mole.
- This value is obtained from the atomic mass listed on the periodic table.

Step-by-Step Calculation of the Mass of Cobalt Sample

To find the mass of a cobalt sample with a known number of atoms, follow these steps:

Step 1: Convert Atoms to Moles

- Since 1 mole of cobalt contains 6.022×10^{23} atoms, the number of moles in your sample is:

$$
\text{Number of moles} = \frac{\text{Number of atoms}}{\text{Avogadro's number}}
$$

- Plugging in the values:

$$
\text{Number of moles} = \frac{3.31 \times 10^{22}}{6.022 \times 10^{23}}
$$

- Perform the division:

$$
\text{Number of moles} \approx 0.0550 \text{ mol}
$$

Step 2: Calculate the Mass from Moles

- Use the molar mass of cobalt to convert moles to grams:

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

- Substituting the known values:

\[

$$
\text{Mass} = 0.0550 \text{ mol} \times 58.93 \text{ g/mol}
$$

- Calculating the result:

$$
\text{Mass} \approx 3.24 \text{ grams}
$$

Complete Calculation Summary

- Atoms given: 3.31×10^{22}
- Atoms to moles: $3.31 \times 10^{22} \div 6.022 \times 10^{23} \approx 0.055$ mol
- Moles to grams: 0.055 mol × 58.93 g/mol ≈ 3.24 grams

Thus, a sample of cobalt containing 3.31×10^{22} atoms has an approximate mass of 3.24 grams.

Additional Tips for Accurate Calculations

While the above calculation provides an accurate estimate, consider the following tips:

Use Precise Atomic Mass Values

- Atomic masses vary slightly depending on isotopic composition.
- For most calculations, use the atomic mass from the periodic table, but note that more precise values can be used if isotope distributions are known.

Pay Attention to Significant Figures

- Keep track of significant figures throughout your calculations to maintain precision.
- In this example, the final answer is rounded to three significant figures.

Be Mindful of Units

- Always ensure units are consistent, especially when converting between atoms, moles, and grams.

Practical Applications of this Calculation

Understanding how to calculate the mass of a sample based on the number of atoms is essential in various fields:

- **Pharmaceuticals:** Determining the mass of active ingredients at the atomic level.
- **Material Science:** Analyzing the composition of alloys or nanomaterials.
- **Environmental Science:** Calculating pollutant quantities based on atomic counts.
- **Academic Research:** Designing experiments involving precise quantities of elements.

By mastering these calculations, scientists and students can better understand chemical reactions, stoichiometry, and material properties at the atomic level.

Conclusion

Calculating the mass of a cobalt sample containing a specific number of atoms is a fundamental task that combines knowledge of Avogadro’s number, molar mass, and unit conversions. In this example, a sample with 3.31×10^{22} atoms of cobalt weighs approximately 3.24 grams. Whether you are studying chemistry, conducting research, or working in an applied science field, mastering this calculation empowers you to quantify substances accurately at the atomic scale. Remember to always verify your atomic masses, handle significant figures properly, and understand the underlying concepts to ensure precise and reliable results.

Frequently Asked Questions

How do I calculate the mass of a cobalt sample containing 3.31×10^{22} atoms?

To calculate the mass, first determine the number of moles using Avogadro's number (6.022×10^{23} atoms/mol), then multiply the moles by cobalt's molar mass (58.93 g/mol). For example, moles = 3.31×10^{22} / 6.022×10^{23} ≈ 0.055 mol, so mass ≈ 0.055 mol × 58.93 g/mol ≈ 3.24 grams.

What is the step-by-step process to find the mass of

cobalt with a given number of atoms?

First, divide the number of atoms (3.31×10^{22}) by Avogadro's number (6.022×10^{23}) to find moles. Next, multiply the moles by cobalt's molar mass (58.93 g/mol) to get the mass in grams. This yields approximately 3.24 grams.

Why do we use Avogadro's number in calculating the mass of a cobalt sample?

Avogadro's number (6.022×10^{23}) relates the number of atoms to moles, allowing us to convert from a count of atoms to a measurable amount of substance (moles), which can then be used to find mass.

If the number of cobalt atoms increases, how does that affect the calculated mass?

The mass increases proportionally with the number of atoms. More atoms mean more moles and thus a greater total mass of cobalt.

Can you estimate the mass of a cobalt sample with fewer atoms, say 1×10^{22} atoms?

Yes. Using the same process, moles = 1×10^{22} / 6.022×10^{23} ≈ 0.0166 mol, and the mass ≈ 0.0166 mol × 58.93 g/mol ≈ 0.977 grams.

What units are used in the calculation of cobalt's mass from the number of atoms?

The result is expressed in grams (g), with the calculation involving atoms, moles, molar mass, and Avogadro's number.

Additional Resources

Calculate The Mass Of A Sample Of Cobalt Containing 3.31x10^22 Atoms

Understanding the precise mass of a substance based on its atomic composition is fundamental in chemistry. Whether for laboratory experiments, industrial applications, or academic research, accurately determining the mass of a sample requires a solid grasp of atomic theory, molar concepts, and unit conversions. Today, we delve into a practical calculation: determining the mass of a cobalt sample containing exactly 3.31×10^{22} atoms. This process exemplifies how microscopic atomic counts translate into macroscopic mass measurements, bridging the gap between the atomic scale and everyday measurements.

Fundamentals of Atomic and Molar Concepts

Before diving into the calculation, it's essential to establish foundational concepts related to atoms, moles, and atomic mass.

Atomic Number and Atomic Mass of Cobalt

- Atomic Number (Z): Cobalt (Co) has an atomic number of 27, meaning each atom contains 27 protons.
- Atomic Mass: The average atomic mass of cobalt is approximately 58.93 atomic mass units (amu). This value, often rounded to 59 g/mol for simplicity, represents the mass of one mole of cobalt atoms.

The Mole Concept

- Definition: A mole (mol) is a standard SI unit representing a specific number of particles—in this case, atoms.
- Avogadro's Number: 1 mol of any substance contains approximately 6.022×10^{23} particles (atoms, molecules, etc.).

Understanding the relationship:

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

where N_A is Avogadro's number.

Calculating the Number of Moles of Cobalt

Given the number of atoms, the first step is to find out how many moles of cobalt this corresponds to.

Step 1: Write down what is known:

- Number of atoms, $N = 3.31 \times 10^{22}$

Step 2: Use Avogadro's number to find moles:

$$
\text{Number of moles} (n) = \frac{N}{N_A}
$$

where:

- $N_A = 6.022 \times 10^{23}$ atoms/mol

Step 3: Perform the calculation:

$$
n = \frac{3.31 \times 10^{22}}{6.022 \times 10^{23}}
$$

Dividing the numbers:

$$
n \approx \frac{3.31}{6.022} \times 10^{(22 - 23)} = 0.550 \times 10^{-1} = 0.0550\, \text{mol}
$$

Result: The sample contains approximately 0.0550 moles of cobalt.

Determining the Mass of the Cobalt Sample

Armed with the number of moles, calculating the mass is straightforward using the molar mass.

Using Molar Mass of Cobalt

- The molar mass of cobalt is approximately 58.93 g/mol.

Step 1: Multiply the number of moles by the molar mass:

$$
\text{Mass} (m) = n \times M
$$

where:

- $n = 0.0550$ mol
- $M = 58.93$ g/mol

Step 2: Perform the multiplication:

$$
m = 0.0550 \times 58.93 \approx 3.241 \text{ grams}
$$

Result: The sample has a mass of approximately 3.24 grams.

Implications and Applications of the Calculation

This calculation illustrates how scientists and chemists translate a count of atoms into a tangible mass. Such conversions are vital across multiple fields.

Laboratory Preparations and Quantitative Analysis

- Precise knowledge of atomic counts allows chemists to prepare solutions with exact molarities.
- In titrations, knowing how many atoms or molecules are involved ensures accuracy and repeatability.

Material Science and Industrial Manufacturing

- Determining the mass of a specific atomic composition is crucial in alloy production, where elemental ratios directly influence material properties.
- For cobalt, used in batteries and superalloys, accurate mass calculations underpin quality control and resource management.

Educational and Research Contexts

- Such calculations serve as fundamental exercises in understanding atomic theory.
- They reinforce concepts like molar relationships, unit conversions, and the significance of Avogadro's number.

Additional Considerations and Variations

While the above calculation assumes pure elemental cobalt, real-world samples often contain impurities. Adjustments might be necessary depending on the purity level.

Impurities and Alloying Elements:

- In industrial contexts, cobalt may be alloyed with other metals, affecting the mass-to-atom ratio.
- Analytical techniques like atomic absorption spectroscopy can quantify purity, refining mass calculations.

Isotopic Variations:

- Natural cobalt is predominantly the isotope \(^{59} \)Co, matching the molar mass used.
- If isotopic composition varies, the molar mass might be adjusted accordingly.

Precision and Rounding:

- For high-precision applications, retain more decimal places during intermediate steps.
- Final results should be rounded based on measurement accuracy and context.

Conclusion: Bridging Atomic Counts and Mass

Calculating the mass of a cobalt sample containing 3.31×10^{22} atoms exemplifies the core principles of chemistry: relating microscopic particles to macroscopic measurements. By understanding atomic masses, molar relationships, and unit conversions, scientists can accurately determine the mass from atomic counts—a process fundamental to laboratory work, material science, and education.

This calculation not only emphasizes the elegance of atomic theory but also underscores its practical utility. Whether preparing chemical solutions, designing materials, or conducting research, the ability to convert between the number of atoms and mass remains a cornerstone of chemical science. As technology advances, such calculations continue to be refined, enabling ever more precise manipulation and understanding of the materials that shape our world.

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