A Mass Of 18.0 G Of An Element Is Known To Contain 4.87 X 1023 Atoms. What Is The Atomic Mass Of The

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Understanding the atomic mass of elements is fundamental in chemistry, enabling scientists to determine quantities, reactiveness, and molecular structures. In this comprehensive guide, we will explore the problem: given a mass of an element and the number of atoms it contains, how do we calculate the atomic mass? Using this specific example—an 18.0-gram sample containing 4.87 x 10^23 atoms—we will outline the step-by-step process to find the atomic mass, discuss relevant concepts, and provide contextual insights to deepen your understanding.

Introduction to Atomic Mass and Its Significance

Atomic mass, often expressed in atomic mass units (amu), is a weighted average of the masses of an atom's isotopes. For pure elements, the atomic mass correlates directly with the mass of a single atom relative to the carbon-12 standard. In practical applications, atomic mass helps chemists:

- Calculate molar masses
- Determine the number of atoms in a given sample
- Convert between mass and number of particles
- Understand chemical reactions at the atomic level

The problem at hand involves connecting the known mass of a sample with the number of atoms it contains to determine the element's atomic mass.

Understanding the Given Data

Before embarking on calculations, let's analyze the provided information:

- Mass of the sample, **m** = 18.0 g
- Number of atoms, **N** = 4.87 x 10^{23}

The goal: Find the **atomic mass** (denoted as *Atomic Mass, M*) of the element.

Fundamental Concepts and Formulas

To determine the atomic mass, we need to understand the relationship between mass, number of atoms, and atomic mass.

Number of Atoms and Moles

- The number of atoms in a sample relates to the number of moles via Avogadro's number.

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

where:

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

- The molar mass (or atomic mass in g/mol) relates the mass of a sample to its amount in moles:

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

Rearranged to find atomic mass:

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

Step-by-Step Calculation

Let's proceed systematically.

Step 1: Calculate the number of moles in the sample

Given:

$$
N = 4.87 \times 10^{23} \text{ atoms}
$$

Using Avogadro's number:

$$
\text{Number of moles} = \frac{N}{N_A} = \frac{4.87 \times 10^{23}}{6.022 \times 10^{23}} \approx 0.809 \text{ mol}
$$

Step 2: Determine the atomic mass

Using the relation:

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

substitute the known values:

$$
\text{Atomic mass} = \frac{18.0\, \text{g}}{0.809\, \text{mol}} \approx 22.25\, \text{g/mol}
$$

Thus, the atomic mass of the element is approximately 22.25 g/mol.

Interpreting the Result

The calculated atomic mass (~22.25 g/mol) suggests the element has an atomic weight close to that of sodium (Na), which has an atomic mass of approximately 23 g/mol. The slight discrepancy arises from rounding during calculations and the approximation of Avogadro's number.

This atomic mass implies that the element could be sodium or a similar element with a comparable atomic weight. In real-world applications, such calculations help identify unknown elements or verify purity.

Additional Insights and Context

Understanding how to derive atomic mass from sample data is crucial in various scientific contexts:

1. Molar Mass and Atomic Mass

- In chemistry, atomic mass (amu) and molar mass (g/mol) are numerically equivalent.
- The molar mass indicates how many grams correspond to one mole of atoms.

2. Role of Avogadro's Number

- Avogadro's number bridges the microscopic world of atoms with macroscopic measurements.
- It defines the number of particles in one mole, serving as a cornerstone of chemical calculations.

3. Practical Applications

- Determining the purity of a sample.
- Calculating the amount of substance needed for reactions.
- Identifying unknown elements via mass and atom count.

4. Common Mistakes to Avoid

- Forgetting to convert between atoms and moles.
- Using incorrect values for Avogadro's number.
- Rounding errors that significantly affect the result.

Extended Example: Variations in Data

Suppose the number of atoms or the mass differs. How does that impact the calculation?

- If the sample mass increases but atoms increase proportionally, the atomic mass remains constant.
- If the number of atoms is known precisely, the calculation becomes straightforward.

For instance, if you have 36.0 g of the element containing 9.74 x 1023 atoms:

$$
\text{Number of moles} = \frac{9.74 \times 10^{23}}{6.022 \times 10^{23}} \approx 1.618\, \text{mol}
$$

$$
\text{Atomic mass} = \frac{36.0\, \text{g}}{1.618\, \text{mol}} \approx 22.25\, \text{g/mol}
$$

Again, confirming the consistency of the calculation.

Conclusion

In summary, determining the atomic mass of an element from a given mass and atom count involves understanding the relationship between mass, moles, and atoms through Avogadro's number. By dividing the number of atoms by Avogadro's number, we find the number of moles, which then allows us to compute the atomic mass by dividing the sample's mass by this molar quantity.

Applying this method to the initial problem:

- Sample mass = 18.0 g
- Number of atoms = 4.87 x 1023
- Calculated atomic mass ≈ 22.25 g/mol

This approach is foundational in analytical chemistry and instrumental in identifying elements, calculating reaction yields, and understanding atomic-scale phenomena.

References and Further Reading

- Atoms, Molecules, and Ions — Chemistry Textbooks
- Avogadro's Number and Its Significance
- Molar Mass and Atomic Mass: Definitions and Relationships
- Practical Chemistry Calculations and Problem-Solving Strategies

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If you need further assistance on atomic mass calculations or related topics, feel free to ask!

Frequently Asked Questions

What is the atomic mass of the element given 18.0 g contains 4.87 x 10^23 atoms?

The atomic mass is approximately 37.0 g/mol.

How do you calculate the atomic mass from the mass and number of atoms?

Divide the total mass by the number of atoms: Atomic mass = 18.0 g / 4.87 x 10^23 atoms ≈ 3.70 x 10^-23 g per atom, then convert to atomic mass units (amu).

What is the significance of knowing the number of atoms in a sample when calculating atomic mass?

Knowing the number of atoms allows for determining the average mass per atom, which is the atomic mass in grams per mole.

How is Avogadro's number related to this problem?

Avogadro's number (6.022 x 10^23 atoms/mol) is used to convert the atomic mass in grams per atom to grams per mole.

Why is the atomic mass often expressed in atomic mass units (amu)?

Atomic mass units provide a convenient way to express the mass of atoms relative to 1/12 of a carbon-12 atom's mass, making calculations more straightforward.

If 18.0 g of an element contains 4.87 x 10^23 atoms, which element could it be?

It could be an element with an atomic mass of approximately 37.0 u, such as chlorine (Cl), which has an atomic mass of about 35.45 u, close to the calculated value.

What are the steps to find the atomic mass from the given data?

Step 1: Calculate the mass per atom by dividing total mass by number of atoms. Step 2: Convert this value to atomic mass units (amu) if necessary. Step 3: Express the atomic mass in grams per mole by multiplying by Avogadro's number.

Can this method be used to find the atomic mass of any element if the number of atoms and total mass are known?

Yes, as long as you know the total mass and number of atoms, you can determine the atomic mass using the same approach.

Additional Resources

A mass of 18.0 g of an element is known to contain 4.87 x 1023 atoms. What is the atomic mass of the element? This question touches on fundamental concepts in chemistry, including atomic mass, Avogadro's number, and how to interpret atomic quantities in practical measurements. Understanding how to determine the atomic mass of an element from given data not only reinforces core chemical principles but also enhances problem-solving skills vital for students and professionals alike.

In this article, we will explore the process step-by-step, breaking down the problem into manageable parts. By the end, you will understand how to analyze similar problems and accurately calculate atomic masses based on given mass and atomic counts.

Understanding the Problem

The problem provides two key pieces of information:
- Mass of the sample: 18.0 grams
- Number of atoms in the sample: 4.87 x 1023 atoms

The question asks: What is the atomic mass of the element?

At first glance, this appears straightforward, but it involves understanding the relationship between mass, number of atoms, and atomic mass.

Core Concepts Needed

Before we proceed with calculations, let's review some essential concepts:

Atomic Mass

- The atomic mass of an element (often expressed in atomic mass units, amu) is the average mass of an atom of that element.
- When expressed in grams per mole (g/mol), the atomic mass tells us how much one mole of the element weighs.

Avogadro's Number

- Avogadro's number (≈6.022 x 1023) is the number of particles (atoms, molecules, etc.) in one mole of a substance.
- This constant allows us to relate the number of atoms to the amount of substance in moles.

Moles and Atomic Mass

- The number of moles of an element in a sample is given by:

$$
\text{Number of moles} = \frac{\text{Mass of sample (g)}}{\text{Atomic mass (g/mol)}}
$$

- Conversely, the number of atoms is related to moles by:

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

where N_A is Avogadro’s number.

Step-by-Step Solution

Let's now approach the problem systematically.

Step 1: Determine the number of moles in the sample

Given:
- Number of atoms = 4.87 x 1023
- Avogadro’s number, N_A = 6.022 x 1023 atoms/mol

Calculate the number of moles:

$$
\text{Number of moles} = \frac{\text{Number of atoms}}{N_A} = \frac{4.87 \times 10^{23}}{6.022 \times 10^{23}}
$$

Perform the division:

$$
\text{Number of moles} \approx \frac{4.87}{6.022} \approx 0.809 \text{ mol}
$$

Step 2: Find the atomic mass

Now, knowing:
- Mass of the sample = 18.0 g
- Moles of the element in the sample ≈ 0.809 mol

The atomic mass (g/mol) is:

$$
\text{Atomic mass} = \frac{\text{Mass of sample}}{\text{Number of moles}} = \frac{18.0\, \text{g}}{0.809\, \text{mol}}
$$

Calculating:

$$
\text{Atomic mass} \approx 22.23\, \text{g/mol}
$$

Interpretation and Final Result

The atomic mass of the element is approximately 22.23 g/mol.

This value suggests that the element in question has an atomic mass similar to that of magnesium, which has an atomic mass of approximately 24.3 g/mol, or sodium at about 23 g/mol. It indicates the element might be close to these in the periodic table, but precise identification would require more data.

Additional Considerations

Accuracy and Rounding

- Throughout calculations, it's essential to maintain appropriate significant figures.
- The final atomic mass has been rounded to two decimal places, consistent with the initial data's precision.

Practical Applications

- Chemical analysis: Determining atomic mass from experimental data is a common task in labs.
- Material identification: Helps in identifying unknown elements or verifying purity.
- Educational purposes: Reinforces understanding of mole concept and atomic scale calculations.

Summary and Key Takeaways

- To find the atomic mass of an element from given mass and atomic count:
1. Convert the number of atoms to moles using Avogadro’s number.
2. Use the relation: $\text{Atomic mass} = \frac{\text{Mass}}{\text{Moles}}$.
- The approach hinges on understanding the relationships between atoms, moles, and mass.
- Precise calculations depend on understanding the constants involved and maintaining significant figures.

Final Thoughts

Mastering the process of calculating atomic mass from experimental data is an essential skill in chemistry. It bridges theoretical understanding with practical application, allowing chemists to analyze unknown samples, verify purity, or explore new materials. By following structured steps—calculating moles from atom counts and then deriving atomic mass—you develop a clear framework that can be applied across various problems involving atomic-scale measurements.

Remember, always double-check your calculations and consider the context of your data to ensure accurate, meaningful results. Whether you're a student tackling homework or a professional conducting research, these fundamental concepts form the backbone of quantitative chemistry analysis.

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