If You Have An 8.53 Mg Sample Of Phosphorus Oxychloride And It Contains 1.72 Mg Of Phosphorus, What Is

If You Have An 8.53 Mg Sample Of Phosphorus Oxychloride And It Contains 1.72 Mg Of Phosphorus, What Is the percentage composition of phosphorus in the compound? How can this information be used to determine the molecular formula of phosphorus oxychloride? What are the practical applications of understanding this composition? This article will explore these questions in depth, providing a comprehensive analysis of the problem, the relevant chemical principles, and the calculations involved.

Understanding the Problem: Basic Concepts and Data

Mass of Sample and Composition

The problem states that you have an 8.53 Mg (megagrams, equivalent to metric tons) sample of phosphorus oxychloride, a chemical compound with the formula $POCl_3$. Within this sample, there is 1.72 Mg of phosphorus. Using this data, we can determine the proportion of phosphorus in the compound, which is fundamental to understanding its composition and properties.

Chemical Formula of Phosphorus Oxychloride

Phosphorus oxychloride ($POCl_3$) is a chemical compound consisting of one phosphorus atom, one oxygen atom, and three chlorine atoms. The molar mass of each element is approximately:
- Phosphorus (P): 30.97 g/mol
- Oxygen (O): 16.00 g/mol
- Chlorine (Cl): 35.45 g/mol

Calculating the molar mass of $POCl_3$:
$$
\text{Molar mass of POCl}_3 = 30.97 + 16.00 + (3 \times 35.45) = 30.97 + 16.00 + 106.35 = 153.32\, \text{g/mol}
$$

Calculating the Percentage of Phosphorus in

$POCl_3$

Step 1: Determine the mass of phosphorus in the sample

The problem provides the mass of phosphorus directly:
$$
\text{Mass of P} = 1.72\, \text{Mg} = 1,720,000\, \text{g}
$$

Step 2: Convert the total sample mass to grams

$$
\text{Total sample mass} = 8.53\, \text{Mg} = 8,530,000\, \text{g}
$$

Step 3: Calculate the mass percentage of phosphorus

$$
\text{Mass \% of P} = \left(\frac{\text{Mass of P}}{\text{Total sample mass}} \right) \times 100
$$
$$
= \left(\frac{1,720,000}{8,530,000} \right) \times 100 \approx 20.17\%
$$

Therefore, phosphorus makes up approximately 20.17% of the total mass of the sample.

Determining the Empirical Formula and Molecular Formula

Understanding the Relationship Between Composition and Formula

Knowing the percentage of phosphorus allows us to estimate the molar ratio of elements in the compound. Since $POCl_3$ is a known compound, this calculation helps verify its purity or determine if the sample is consistent with the known molecular formula.

Step 1: Calculate the moles of phosphorus in the sample

$$
\text{Moles of P} = \frac{\text{Mass of P}}{\text{Atomic mass of P}} = \frac{1,720,000\, \text{g}}{30.97\, \text{g/mol}} \approx 55,526\, \text{mol}
$$

Step 2: Calculate the moles of the entire sample

$$
\text{Moles of POCl}_3 = \frac{\text{Total sample mass}}{\text{Molar mass of POCl}_3} = \frac{8,530,000\, \text{g}}{153.32\, \text{g/mol}} \approx 55,593\, \text{mol}
$$

Step 3: Determine the ratio of P in the compound

Since the molar amount of phosphorus (55,526 mol) closely matches the molar amount of $POCl_3$ (55,593 mol), this confirms that the compound is predominantly $POCl_3$, with a molar ratio of approximately 1:1.

This confirms that the sample's composition aligns with the molecular formula $POCl_3$.

Implications of the Composition: Practical Applications and Significance

Understanding Chemical Purity and Composition

Accurate knowledge of the percentage of phosphorus in the sample allows chemists to assess purity. If the calculated percentage deviates significantly from the theoretical value (~20.2%), it suggests impurities or incomplete reactions.

Use in Industrial and Laboratory Settings

Phosphorus oxychloride is widely used in:
- The synthesis of organophosphorus compounds
- Production of phosphates
- As a dehydrating agent in chemical reactions

Knowing the exact composition ensures quality control in manufacturing processes.

Safety and Handling Considerations

Since $POCl_3$ is corrosive and reacts with water to produce hazardous fumes, understanding its purity and composition helps in risk assessment, proper storage, and handling procedures.

Additional Calculations and Considerations

Determining the Mole Fraction of Phosphorus

The mole fraction of phosphorus in the compound can be calculated:

$$
\text{Mole fraction of P} = \frac{\text{Moles of P}}{\text{Moles of POCl}_3} \approx \frac{55,526}{55,593} \approx 0.998
$$

This value close to 1 confirms the 1:1 ratio in the compound.

Mass of Other Elements in the Sample

- Oxygen:

$$
\text{Mass of O} = \text{Moles of POCl}_3 \times 16.00\, \text{g/mol} \approx 55,593 \times 16.00 \approx 889,488\, \text{g}
$$

- Chlorine:

$$
\text{Mass of Cl} = 3 \times 55,593 \times 35.45 \approx 3 \times 55,593 \times 35.45 \approx 5,911,300\, \text{g}
$$

However, these calculations are more illustrative; the actual mass of oxygen and chlorine in the sample can be directly derived from the molar ratios and total mass.

Conclusion

Analyzing the given data reveals that the phosphorus oxychloride sample is predominantly composed of $POCl_3$, with approximately 20.17% phosphorus by mass. The close alignment of molar ratios confirms the compound's molecular formula. Such detailed understanding of composition is vital across multiple domains, from quality control in manufacturing to safety protocols and chemical research.

In summary:
- The percentage of phosphorus in the sample is approximately 20.17%.

- The molar ratio of elements aligns with the known molecular formula $POCl_3$.
- This analysis aids in verifying purity, understanding reactivity, and ensuring safe handling procedures.

Understanding the detailed composition of chemical compounds like phosphorus oxychloride allows chemists and industry professionals to optimize processes, ensure safety, and develop new applications based on accurate chemical data.

Frequently Asked Questions

What is the molar mass of phosphorus oxychloride ($POCl_3$)?

The molar mass of $POCl_3$ is approximately 153.33 g/mol, calculated as P (30.97 g/mol) + O (16.00 g/mol) + 3 × Cl (3 × 35.45 g/mol).

How do you determine the amount of phosphorus in a sample of phosphorus oxychloride?

You multiply the total mass of the sample by the mass fraction of phosphorus, which is the molar mass of phosphorus divided by the molar mass of $POCl_3$. In this case, (1.72 Mg P) / (Total mass) gives the phosphorus content proportion.

What is the percentage of phosphorus in the phosphorus oxychloride sample?

Percentage of phosphorus = (Mass of phosphorus / Total mass of sample) × 100 = (1.72 Mg / 8.53 Mg) × 100 ≈ 20.16%.

How can I find the amount of other elements in the sample, such as chlorine or oxygen?

Calculate their molar masses and multiply by their respective molar ratios in $POCl_3$, then determine their mass contributions based on the total sample weight.

If the sample contains 1.72 Mg of phosphorus, how much phosphorus oxychloride does it contain?

The sample contains 8.53 Mg of phosphorus oxychloride total. Since 1.72 Mg of phosphorus is present, it indicates that approximately 8.53 Mg of $POCl_3$ is in the sample, consistent with the initial data.

What is the significance of knowing the phosphorus content in phosphorus oxychloride?

It helps in calculating the purity of the compound, determining the exact amount of active phosphorus, and is essential for chemical reactions or industrial applications involving phosphorus oxychloride.

How do you convert the mass of phosphorus in Mg to moles?

Divide the mass of phosphorus by its molar mass: 1.72 Mg (or 1720 g) / 30.97 g/mol ≈ 55.55 mol of phosphorus.

What calculations are needed to determine the mass of phosphorus oxychloride from the phosphorus content?

Use the molar ratio of phosphorus to $POCl_3$. Since each mole of $POCl_3$ contains one mole of phosphorus, the mass of $POCl_3$ = molar mass of $POCl_3$ × (moles of phosphorus).

Is the sample pure phosphorus oxychloride based on the given data?

Based solely on the phosphorus content (1.72 Mg in an 8.53 Mg sample), the phosphorus makes up approximately 20.16%, but purity assessment requires considering other impurities or components present.

What are the next steps for analyzing the composition of the sample further?

Perform additional chemical analyses such as chromatography or spectrometry to identify and quantify impurities, ensuring accurate purity and composition data.

Additional Resources

If You Have An 8.53 Mg Sample Of Phosphorus Oxychloride And It Contains 1.72 Mg Of Phosphorus, What Is—these types of questions are fundamental in chemical analysis, stoichiometry, and material characterization. Understanding how to interpret and manipulate such data is crucial for chemists, chemical engineers, and laboratory professionals. In this comprehensive guide, we will explore how to determine the composition, calculate the purity, and understand the significance of the given data involving phosphorus oxychloride ($POCl_3$). We will break down the problem step-by-step, providing clarity on concepts such as molar mass, mass

percentage, and purity calculations.

Introduction

Phosphorus oxychloride ($POCl_3$) is an inorganic compound widely used as a pesticide, flame retardant, and precursor in the synthesis of various phosphorus compounds. It is a colorless, corrosive liquid with the formula $POCl_3$. When analyzing a sample, knowing the mass of the sample and the amount of specific elements contained within it helps determine its purity and composition.

In the scenario provided, you have an 8.53 Mg (megagrams) sample of phosphorus oxychloride that contains 1.72 Mg of phosphorus. This data offers a starting point to answer multiple questions, such as:

- What is the mass percentage of phosphorus in the sample?
- What is the molar mass of phosphorus oxychloride?
- What is the percentage purity of the sample?
- How does the composition inform us about the sample's quality?

Understanding the Data and Relevant Concepts

Key Data Points:
- Total sample mass: 8.53 Mg
- Phosphorus mass in sample: 1.72 Mg

Basic Concepts:
- Mass percentage: The proportion of a specific element or compound relative to the total mass.
- Molar mass: The mass of one mole of a substance, calculated from atomic weights.
- Purity: The degree to which the sample is free from impurities, often expressed in percentage.

Step 1: Convert Megagrams to Kilograms or Grams

Since the molecular weights and calculations are typically performed in grams, convert the data accordingly:

- 1 Mg = 1,000,000 grams

Sample mass:
- 8.53 Mg = 8.53 × 1,000,000 g = 8,530,000 g

Phosphorus content:

- 1.72 Mg = 1.72 × 1,000,000 g = 1,720,000 g

Step 2: Calculate the Mass Percentage of Phosphorus

The mass percentage of phosphorus in the sample is the ratio of phosphorus mass to total sample mass, expressed as a percentage:

$$
\text{Mass \% of P} = \left(\frac{\text{Mass of P}}{\text{Total mass of sample}} \right) \times 100
$$

Plugging in the values:

$$
\text{Mass \% of P} = \left(\frac{1,720,000\, g}{8,530,000\, g} \right) \times 100 \approx 20.15\%
$$

Interpretation: The sample contains approximately 20.15% phosphorus by mass.

Step 3: Determine the Molar Mass of Phosphorus Oxychloride ($POCl_3$)

Calculating the molar mass helps understand the composition at the molecular level.

Element	Atomic Weight (g/mol)	Number of Atoms in $POCl_3$
P	30.97	1
O	16.00	1
Cl	35.45	3

Molar mass of $POCl_3$:

$$
\text{M}_{\text{POCl}_3} = (1 \times 30.97) + (1 \times 16.00) + (3 \times 35.45) \\
= 30.97 + 16.00 + 106.35 = 153.32\, \text{g/mol}
$$

Step 4: Calculate the Theoretical Mass of Phosphorus in Pure $POCl_3$

In pure $POCl_3$:

$$
\[

$$
\text{Mass \% of P} = \left(\frac{\text{Atomic weight of P}}{\text{Molar mass of POCl}_3} \right) \times 100
$$

$$
= \left(\frac{30.97}{153.32} \right) \times 100 \approx 20.21\%
$$

Observation: The theoretical mass percentage of phosphorus in pure $POCl_3$ is approximately 20.21%.

Step 5: Comparing Actual and Theoretical Phosphorus Content

From the data, the actual phosphorus content is 20.15%, while the theoretical value for pure $POCl_3$ is 20.21%. The slight difference suggests:

- The sample is highly pure, with minimal impurities.
- The phosphorus content aligns closely with what's expected in pure $POCl_3$.

Step 6: Determine the Purity of the Sample

The purity can be assessed by comparing the measured phosphorus content with the theoretical value:

$$
\text{Purity (\%)} = \left(\frac{\text{Measured P \%}}{\text{Theoretical P \%}} \right) \times 100
$$

$$
= \left(\frac{20.15}{20.21} \right) \times 100 \approx 99.7\%
$$

Interpretation: The sample is approximately 99.7% pure, indicating a high-quality phosphorus oxychloride sample with minimal impurities.

Step 7: Additional Analysis—Determining the Actual Mass of $POCl_3$

Knowing the mass of phosphorus in the sample and the molar ratio allows us to estimate the total amount of $POCl_3$.

- The mass ratio of phosphorus to $POCl_3$:

$$
\text{Mass ratio} = \frac{\text{Mass of P}}{\text{Mass of POCl}_3} \approx
$$

0.2021
\]

- Therefore, the total mass of $POCl_3$ in the sample:

\[
\text{Mass of POCl}_3 = \frac{\text{Mass of P}}{0.2021} \approx
\frac{1,720,000\, g}{0.2021} \approx 8,512,416\, g
\]

This closely matches the total sample mass, confirming the high purity.

Final Considerations and Practical Implications

Summary of Key Findings:
- The mass percentage of phosphorus in your sample is approximately 20.15%.
- The theoretical phosphorus content in pure $POCl_3$ is about 20.21%.
- The purity of your sample is roughly 99.7%, indicating a highly pure compound.
- The total amount of $POCl_3$ in the sample is approximately 8.512 Mg.

Practical Applications:
- Quality Control: These calculations help verify the purity of chemical batches.
- Stoichiometric Calculations: Knowing the precise composition enables accurate reactions and synthesis planning.
- Material Certification: Ensures that the material meets specifications for industrial or research use.

Conclusion

Analyzing a sample of phosphorus oxychloride with known phosphorus content involves understanding basic principles of chemistry and stoichiometry. The process includes converting units, calculating mass percentages, comparing experimental data to theoretical values, and determining purity. Such detailed analysis ensures quality assurance and precise application of chemicals in various industrial and research settings.

By following this step-by-step guide, professionals can confidently interpret similar datasets, optimize processes, and maintain high standards in chemical analysis.

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