What Is The Maximum Number Of Grams Of PH3 That Can Be Formed When 4.62 G Of Phosphorus Reacts With 2.58

What Is The Maximum Number Of Grams Of PH3 That Can Be Formed When 4.62 G Of Phosphorus Reacts With 2.58 is a common question in stoichiometry, a fundamental concept in chemistry that involves calculating the quantities of reactants and products in chemical reactions. Understanding how to determine the maximum amount of phosphine (PH_3) that can be produced from given reactants is essential for students, chemists, and anyone interested in chemical synthesis. In this article, we will explore the detailed process of calculating the maximum grams of PH_3 formed when 4.62 grams of phosphorus reacts with 2.58 grams of hydrogen, including the relevant chemical equations, molar calculations, and stoichiometric principles.

Understanding the Reaction: Phosphorus and Hydrogen to Form PH_3

The Balanced Chemical Equation

The formation of phosphine (PH_3) from phosphorus and hydrogen gas involves a straightforward chemical reaction:

$P_4 + 6\ H_2 \rightarrow 4\ PH_3$

This equation indicates that one mole of tetraphosphorus (P_4) reacts with six moles of hydrogen gas (H_2) to produce four moles of phosphine (PH_3).

Key Points About the Reaction

- Reactants: Phosphorus (P_4) and hydrogen gas (H_2)
- Product: Phosphine (PH_3)
- Mole ratios: 1 mol P_4 : 6 mol H_2 : 4 mol PH_3
- Molecular weights:
- P_4: approximately 123.88 g/mol (since atomic P ≈ 30.97 g/mol)
- H_2: approximately 2.02 g/mol
- PH_3: approximately 34.00 g/mol

Understanding these ratios and molecular weights is crucial for the subsequent calculations.

Step-by-Step Calculation of the Maximum Grams of PH_3

1. Convert Given Masses to Moles

To determine the limiting reactant, we first convert the given masses of phosphorus and hydrogen into moles.

- **Phosphorus:** 4.62 g P
- **Hydrogen:** 2.58 g H_2

Calculations:
- Moles of P_4 = mass / molar mass = 4.62 g / 123.88 g/mol ≈ 0.0373 mol
- Moles of H_2 = 2.58 g / 2.02 g/mol ≈ 1.28 mol

2. Determine the Limiting Reactant

Using the molar ratios from the balanced equation:

- For phosphorus (P_4):
- 1 mol P_4 produces 4 mol PH_3
- For hydrogen (H_2):
- 6 mol H_2 produce 4 mol PH_3

Calculate the potential amount of PH_3 produced from each reactant:

- **From phosphorus:** 0.0373 mol P_4 × (4 mol PH_3 / 1 mol P_4) = 0.1492 mol PH_3
- **From hydrogen:** 1.28 mol H_2 × (4 mol PH_3 / 6 mol H_2) ≈ 0.853 mol PH_3

Since the amount of PH_3 formed based on phosphorus is less (0.1492 mol) compared to hydrogen, phosphorus is the limiting reactant.

3. Calculate the Theoretical Maximum Mass of PH_3

Using the limiting reactant (phosphorus):

- Moles of PH_3 produced = 0.1492 mol
- Molar mass of PH_3 ≈ 34.00 g/mol

Mass of PH_3 = moles × molar mass = 0.1492 mol × 34.00 g/mol ≈ 5.07 g

Therefore, the maximum grams of PH_3 that can be formed are approximately 5.07 grams.

Additional Considerations in the Calculation

Reaction Efficiency and Yield

The calculation above assumes a 100% yield, which is idealized. In practical scenarios, reaction efficiency might be less, affecting the actual amount of PH_3 produced.

Purity of Reactants

Impurities in phosphorus or hydrogen could impact the actual yield, so real-world results may differ.

Safety Precautions When Handling PH_3

Phosphine is a highly toxic and flammable gas, and any synthesis should be performed with proper safety measures in a controlled laboratory environment.

Summary of the Calculation Process

To summarize the steps involved:

1. Convert the given masses of reactants to moles.
2. Use the balanced chemical equation to determine the mole ratios.
3. Identify the limiting reactant based on the mole ratios.
4. Calculate the maximum moles of PH_3 that can be produced from the limiting reactant.
5. Convert moles of PH_3 to grams to find the maximum mass that can be

formed.

In this case, with 4.62 grams of phosphorus and 2.58 grams of hydrogen, approximately 5.07 grams of PH_3 can be formed, with phosphorus being the limiting reactant.

Conclusion

Understanding how to determine the maximum amount of a product formed in a chemical reaction is a fundamental skill in chemistry, especially in stoichiometry. By carefully converting masses to moles, using the balanced chemical equation to find mole ratios, and identifying the limiting reactant, chemists can accurately predict product yields. For the reaction between phosphorus and hydrogen to form phosphine, the limiting reactant approach reveals that about 5.07 grams of PH_3 can be synthesized from 4.62 grams of phosphorus and 2.58 grams of hydrogen, assuming complete and efficient reaction conditions.

If you're tackling similar problems, remember to always verify the molar ratios and consider real-world factors like reaction yield and purity to get the most accurate predictions.

Frequently Asked Questions

What is the maximum amount of phosphine (PH_3) that can be produced when 4.62 g of phosphorus reacts with 2.58 g of hydrogen?

The maximum mass of PH_3 that can be formed is approximately 2.35 grams, assuming complete reaction of the limiting reagent.

How do you determine which reactant limits the formation of PH_3 in this reaction?

By calculating the molar amounts of phosphorus and hydrogen available and comparing their mole ratios to the reaction's stoichiometry, the limiting reagent can be identified as the one producing the lesser amount of product.

What is the balanced chemical equation for the

formation of phosphine from phosphorus and hydrogen?

The balanced chemical equation is $P_4 + 6H_2 \rightarrow 4PH_3$.

How do you calculate the theoretical yield of PH_3 in grams from given quantities of reactants?

First, convert the masses of reactants to moles, identify the limiting reagent, then use the mole ratio from the balanced equation to find moles of PH_3 formed, and finally convert that to grams using PH_3's molar mass.

If 4.62 g of phosphorus is used, what is the limiting reagent when reacting with 2.58 g of hydrogen?

Calculations show that phosphorus is the limiting reagent, meaning it determines the maximum amount of PH_3 that can be produced under the given conditions.

Additional Resources

What Is The Maximum Number Of Grams Of PH_3 That Can Be Formed When 4.62 G Of Phosphorus Reacts With 2.58 G Of Hydrogen?

Understanding the maximum amount of phosphine (PH_3) that can be produced from given quantities of phosphorus and hydrogen is a fundamental concept in stoichiometry, a core principle in chemistry. This calculation involves determining the limiting reagent, which is the reactant that determines the maximum product yield. When considering the reaction of phosphorus with hydrogen to form phosphine, carefully analyzing the molar relationships and using stoichiometric ratios allows chemists to predict the theoretical maximum grams of PH_3 that can be generated from specified reactants. This type of problem not only hones problem-solving skills but also deepens the comprehension of chemical reactions, molar conversions, and limiting reagent concepts.

Introduction to the Reaction

The chemical reaction between phosphorus and hydrogen to produce phosphine (PH_3) can be represented as:

$$ \text{P}_4 + 6 \text{H}_2 \rightarrow 4 \text{PH}_3 $$

This balanced equation indicates that:

- 1 mole of P_4 reacts with 6 moles of H_2

- Produces 4 moles of PH_3

However, in many cases, the reactants may not be in the exact molar ratios required, leading to the concept of limiting reagents. Determining which reactant is limiting allows us to calculate the maximum amount of product that can be formed.

Step-by-Step Guide to the Calculation

Step 1: Write the Balanced Chemical Equation

The key step in any stoichiometry problem is to start with the correct, balanced chemical equation. For phosphorus (P_4) and hydrogen (H_2) forming phosphine (PH_3), the balanced reaction is:

$$ \text{P}_4 + 6 \text{H}_2 \rightarrow 4 \text{PH}_3 $$

This tells us:

- 1 mol of P_4 produces 4 mol of PH_3
- 6 mol of H_2 produces 4 mol of PH_3

Step 2: Convert Given Masses to Moles

Given data:

- Phosphorus (P): 4.62 g
- Hydrogen (H_2): 2.58 g

Atomic masses:

- P = 30.97 g/mol
- H_2 = 2.016 g/mol

Calculations:

- Moles of P:

$$
\text{Moles of P} = \frac{4.62\, \text{g}}{30.97\, \text{g/mol}} \approx 0.149\, \text{mol}
$$

- Moles of H_2:

$$
\text{Moles of H}_2 = \frac{2.58\, \text{g}}{2.016\, \text{g/mol}} \approx 1.28\, \text{mol}
$$

Step 3: Determine the Limiting Reagent

Compare the molar ratios of reactants to the coefficients in the balanced equation:

- From the balanced equation, 1 mol of P_4 reacts with 6 mol of H_2.
- Our initial amounts correspond to:

- P: 0.149 mol (equivalent to roughly 0.149 mol of P_4, since P is in the form P_4)
- H_2: 1.28 mol

Note: Since phosphorus is provided as P, but the balanced equation involves P_4, we need to convert the moles of P to P_4:

$$
\text{Moles of P}_4 = \frac{\text{Moles of P}}{4} = \frac{0.149}{4} \approx 0.0373\, \text{mol}
$$

Now, compare the molar ratios:

- Required for P_4: 1 mol P_4 reacts with 6 mol H_2
- For 0.0373 mol P_4, the required H_2:

$$
0.0373\, \text{mol P}_4 \times 6 = 0.224\, \text{mol H}_2
$$

- Actual H_2 available: 1.28 mol

Since 0.224 mol H_2 is needed but 1.28 mol is available, hydrogen is in excess, and phosphorus (or P_4) is the limiting reagent.

Conclusion: Phosphorus (P_4) is the limiting reagent.

Step 4: Calculate the Moles of PH_3 Produced

Using the limiting reagent, P_4:

- From the balanced equation:

$$
1\, \text{mol P}_4 \rightarrow 4\, \text{mol PH}_3
$$

- Therefore, the moles of PH_3 produced:

$$
\

$$
\text{Moles of PH}_3 = 0.0373\, \text{mol P}_4 \times 4 = 0.149\, \text{mol}
$$

Step 5: Convert Moles of PH_3 to Grams

- Molar mass of PH_3:

$$
(1 \times 30.97) + (3 \times 1.008) = 34.95\, \text{g/mol}
$$

- Grams of PH_3:

$$
0.149\, \text{mol} \times 34.95\, \text{g/mol} \approx 5.21\, \text{g}
$$

Final Answer:

The maximum number of grams of PH_3 that can be formed when 4.62 g of phosphorus reacts with 2.58 g of hydrogen is approximately 5.21 grams.

Additional Considerations

1. Limiting Reagent Significance

The concept of limiting reagent is critical in chemical synthesis, especially in industrial processes where maximizing yield is essential. In this problem, phosphorus limits the amount of phosphine produced, despite excess hydrogen.

2. Theoretical vs. Actual Yield

While the calculation provides the theoretical maximum grams of PH_3, actual yields may be lower due to reaction inefficiencies, side reactions, or incomplete reactions.

3. Unit Conversions and Precision

Always verify unit conversions and keep track of significant figures. Here, the final answer is rounded to three significant figures for clarity and precision.

4. Environmental and Safety Notes

Handling phosphorus and phosphine requires caution, as PH_3 is highly toxic

and flammable. Proper laboratory safety protocols are essential.

Summary

In conclusion, by carefully analyzing the balanced chemical equation, converting masses to moles, identifying the limiting reagent, and applying molar ratios, we determine that approximately 5.21 grams of phosphine (PH_3) can be formed from 4.62 g of phosphorus reacting with 2.58 g of hydrogen. This exercise exemplifies the power of stoichiometry in predicting product yields and underscores the importance of understanding molar relationships in chemical reactions.

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