(c) 45 G C,H, React With 45 G Cl According To The Equation:Cl + C6H6 C6H5Cl + HCI. What Is The Limiting

(c) 45 G C,H, React With 45 G Cl According To The Equation: Cl + C6H6 → C6H5Cl + HCl. What Is The Limiting?

Understanding chemical reactions and the concept of limiting reagents is fundamental in chemistry, particularly when dealing with reactions involving organic compounds and halogens. In this article, we will examine the reaction between 45 grams of a hydrocarbon, likely benzene (C_6H_6), with 45 grams of chlorine (Cl_2), following the equation:

$Cl_2 + C_6H_6 \rightarrow C_6H_5Cl + HCl$

Our goal is to determine which reactant is the limiting reagent—meaning the reactant that will be completely consumed first, thus limiting the amount of product formed. We will explore the reaction's stoichiometry, mole calculations, and the concept of limiting reagents in detail to provide clarity.

Understanding the Reaction: Chlorination of Benzene

Reaction Overview

The reaction in question is a typical halogenation of benzene, where chlorine reacts with benzene to produce chlorobenzene (C_6H_5Cl) and hydrogen chloride (HCl). The balanced chemical equation is:

$Cl_2 + C_6H_6 \rightarrow C_6H_5Cl + HCl$

This indicates a 1:1 molar ratio between chlorine molecules and benzene molecules.

Significance of Limiting Reagents

In any chemical reaction, the limiting reagent determines the maximum amount of product that can be formed. It is essential to identify the limiting reagent for accurate yield predictions and reaction efficiency assessments.

Step-by-Step Calculation to Determine the Limiting Reagent

Step 1: Convert Grams to Moles

Since the reaction is based on molar ratios, we need to convert the given masses into moles.

Given Data:

- Mass of benzene (C_6H_6): 45 g
- Mass of chlorine (Cl_2): 45 g

Molar masses:

- C_6H_6 (benzene):
Carbon (C): 12.01 g/mol × 6 = 72.06 g/mol
Hydrogen (H): 1.008 g/mol × 6 = 6.048 g/mol
Total: 78.11 g/mol

- Cl_2 (chlorine molecule):
Cl: 35.45 g/mol × 2 = 70.90 g/mol

Calculations:

- Moles of benzene:
$\text{moles C}_6\text{H}_6 = \frac{45\, \text{g}}{78.11\, \text{g/mol}} \approx 0.576 \text{ mol}$

- Moles of chlorine:
$\text{moles Cl}_2 = \frac{45\, \text{g}}{70.90\, \text{g/mol}} \approx 0.634 \text{ mol}$

Step 2: Analyze the Stoichiometry

The balanced chemical equation shows a 1:1 molar ratio:

$Cl_2 : C_6H_6 = 1 : 1$

Thus:

- 1 mol of Cl_2 reacts with 1 mol of benzene
- To react completely:

- Cl_2 required: 0.576 mol (since benzene is 0.576 mol)
- Cl_2 available: 0.634 mol

Observation:
Since 0.634 mol of Cl_2 is available, which is more than the 0.576 mol needed for the benzene present, chlorine is in excess.

- Benzene: 0.576 mol
- Cl_2: 0.634 mol

Conclusion:
Benzene is the limiting reagent because it will be completely consumed first, limiting the formation of chlorobenzene.

Determining the Amount of Product Formed

Since benzene is limiting, the maximum amount of chlorobenzene produced corresponds to the moles of benzene reacted.

Calculations:

- Moles of chlorobenzene formed:
1 mol C_6H_6 → 1 mol C_6H_5Cl

- Moles of chlorobenzene: 0.576 mol

- Molar mass of chlorobenzene (C_6H_5Cl):
Carbon: 12.01 g/mol × 6 = 72.06 g/mol
Hydrogen: 1.008 g/mol × 5 = 5.04 g/mol
Chlorine: 35.45 g/mol
Total: 112.55 g/mol

Mass of chlorobenzene produced:

\(0.576\, \text{mol} \times 112.55\, \text{g/mol} \approx 64.9\, \text{g} \)

Mass of HCl formed:

- 1 mol of benzene produces 1 mol of HCl

- Molar mass of HCl: 36.46 g/mol

\(0.576\, \text{mol} \times 36.46\, \text{g/mol} \approx 21.0\, \text{g} \)

Additional Considerations in the Reaction

Reaction Conditions and Yield

In practice, the reaction conditions such as temperature, catalysts (like $FeCl_3$), and presence of sunlight influence the efficiency and yield. The calculation above assumes 100% conversion, which is rarely achieved in laboratory or industrial settings.

Purity of Reactants

Impurities in reactants can also affect the limiting reagent calculation, but in theoretical calculations, pure substances are assumed.

Side Reactions

Chlorination of benzene can lead to poly-chlorinated products if excess chlorine and specific conditions are used. However, for simplicity, this analysis considers only mono-chlorination.

Summary of Key Points

- Convert given masses to moles using molar masses.
- Compare molar ratios based on the balanced chemical equation.
- The reactant with fewer moles relative to the stoichiometric ratio is the limiting reagent.
- Calculate the theoretical yields of products based on limiting reagent quantities.

Conclusion

Based on the calculations, benzene (C_6H_6) is the limiting reagent in the reaction with 45 grams of chlorine. The excess chlorine ensures that all benzene molecules react, producing approximately 64.9 grams of chlorobenzene and 21 grams of hydrogen chloride, assuming ideal conditions.

Understanding the concept of limiting reagents allows chemists to optimize reactions, predict yields accurately, and minimize waste. It is a fundamental aspect of stoichiometry that is applicable across all types of chemical reactions, whether organic or inorganic.

FAQs About Limiting Reagents in Organic Reactions

1. **What is a limiting reagent?**
   The reactant that is completely consumed in a chemical reaction, limiting the amount of product formed.

2. **Why is it important to identify the limiting reagent?**
   To optimize reactions, improve yields, and reduce waste by knowing which reactant to use in excess.

3. **How do you determine the limiting reagent?**
   By converting reactants to molar quantities, comparing their ratios to the balanced equation, and identifying which is in lesser amount relative to the required molar ratio.

4. **Can there be more than one limiting reagent?**
   Generally, only one reactant limits the reaction, but in complex reactions, multiple limiting reagents can exist if multiple products are formed.

This comprehensive guide should help you understand how to determine the limiting reagent in the chlorination of benzene, interpret stoichiometric calculations accurately, and apply these principles to similar chemical reactions.

Frequently Asked Questions

What is the chemical reaction between chlorine (Cl) and benzene (C6H6)?

The reaction is $Cl + C_6H_6 \rightarrow C_6H_5Cl + HCl$, where chlorine substitutes a hydrogen atom on benzene to form chlorobenzene and hydrogen chloride.

How do you determine the limiting reagent in the reaction of 45 g of chlorine with benzene?

Convert the masses to moles using molar masses, then compare the mole ratios of Cl and C_6H_6 to the stoichiometric ratio to identify the limiting reagent.

What is the molar mass of chlorine (Cl) and benzene (C6H6)?

The molar mass of Cl is approximately 35.45 g/mol, and that of benzene is about 78.11 g/mol.

How much benzene is required to completely react with 45 g of chlorine?

First, calculate moles of Cl: $45\ g \div 35.45\ g/mol \approx 1.27\ mol$. Since the molar ratio is 1:1, 1.27 mol of benzene is needed, which is about $1.27 \times 78.11\ g \approx 99.2\ g$.

If 45 g of chlorine is used, how much benzene is in excess and what is the limiting reagent?

Given the molar amounts, chlorine is the limiting reagent because only 1.27 mol is available, requiring approximately 99.2 g of benzene, which is often in excess if more than that is present.

Why is understanding the limiting reagent important in this chlorination reaction?

Knowing the limiting reagent helps determine the maximum amount of chlorobenzene produced and ensures efficient use of reactants in the reaction process.

Additional Resources

Understanding the Reaction Between Chlorine and Benzene: A Comprehensive

Analysis of Limiting Reactant and Reaction Mechanism

Introduction

The reaction between chlorine (Cl_2) and benzene (C_6H_6) to produce chlorobenzene (C_6H_5Cl) and hydrogen chloride (HCl) is a fundamental example of aromatic substitution chemistry. This process, often referred to as a halogenation of benzene, is pivotal in organic synthesis, materials development, and industrial chemistry.

This review aims to dissect the reaction thoroughly, focusing on the stoichiometry, reaction mechanism, limiting reactant determination, and practical considerations. We will interpret the reaction equation:

$Cl_2 + C_6H_6 \rightarrow C_6H_5Cl + HCl$

and analyze what happens when 45 grams of chlorine reacts with 45 grams of benzene, identifying the limiting reagent and understanding the underlying principles.

Background & Significance of Aromatic Halogenation

Aromatic compounds like benzene are characterized by their stability due to delocalized π-electrons within the aromatic ring. Reacting benzene with halogens typically requires a catalyst (usually $FeCl_3$ or $AlCl_3$) to facilitate electrophilic substitution, though the provided equation omits catalysts for simplicity.

The halogenation of benzene is an electrophilic aromatic substitution (EAS) reaction, where a hydrogen atom on the benzene ring is replaced by a halogen atom. This transformation is essential in synthesizing chlorinated aromatic compounds used in dyes, pharmaceuticals, and agrochemicals.

The Reaction Equation and Its Stoichiometry

The fundamental chemical equation:

$Cl_2 + C_6H_6 \rightarrow C_6H_5Cl + HCl$

In this process:

- Reactants: Chlorine (Cl_2) and benzene (C_6H_6)
- Products: Chlorobenzene (C_6H_5Cl) and hydrogen chloride (HCl)

The reaction shows a 1:1 molar ratio between Cl_2 and benzene, implying that one mole of chlorine reacts with one mole of benzene to produce one mole of chlorobenzene and one mole of HCl.

Calculating Moles of Reactants

To determine the limiting reactant, we must convert the provided masses into moles:

1. Moles of Chlorine (Cl_2):

- Molecular weight of Cl_2:
2×35.45 g/mol = 70.90 g/mol

- Given mass of Cl_2: 45 g

- Moles of Cl_2:
\[
\text{Moles of Cl}_2 = \frac{45 \text{ g}}{70.90 \text{ g/mol}} \approx 0.634 \text{ mol}
\]

2. Moles of Benzene (C_6H_6):

- Molecular weight of C_6H_6:
$(6 \times 12.01) + (6 \times 1.008) = 72.06 + 6.048 \approx 78.11$ g/mol

- Given mass of C_6H_6: 45 g

- Moles of C_6H_6:
\[
\text{Moles of C}_6\text{H}_6 = \frac{45 \text{ g}}{78.11 \text{ g/mol}} \approx 0.576 \text{ mol}
\]

Determining the Limiting Reactant

Given the molar ratios:

- $Cl_2 : C_6H_6 = 1 : 1$

Comparing the moles:

- Cl_2: ~0.634 mol
- C_6H_6: ~0.576 mol

Since the reaction requires equal molar amounts, the reactant with fewer moles relative to the stoichiometry will be the limiting reactant.

Analysis:

- Cl_2 has more molar amount (0.634 mol) than benzene (0.576 mol).
- Benzene is present in a smaller molar ratio relative to Cl_2.

Conclusion:

Benzene (C_6H_6) is the limiting reactant because it is present in fewer moles relative to the amount of chlorine available.

Implications of Limiting Reactant Identification

Understanding the limiting reactant is crucial for:

- Predicting the maximum yield of chlorobenzene.
- Calculating the theoretical amount of products formed.
- Optimizing reaction conditions in industrial processes.
- Avoiding excess reagents that do not contribute to product formation, thus reducing waste and cost.

Calculating Theoretical Yield of Chlorobenzene

Given that benzene is limiting, and based on the molar ratio:

- 1 mol of benzene produces 1 mol of chlorobenzene.

Therefore:

- Moles of chlorobenzene formed = moles of limiting reagent (benzene) = 0.576 mol

Mass of chlorobenzene:

- Molecular weight of C_6H_5Cl:
$6 \times 12.01 + 5 \times 1.008 + 35.45 = 72.06 + 5.04 + 35.45 \approx 112.55$ g/mol

- Mass of chlorobenzene:

$$
0.576 \text{ mol} \times 112.55 \text{ g/mol} \approx 64.88 \text{ g}
$$

Result:

Maximum theoretical yield of chlorobenzene = approximately 64.88 grams

---

Practical Considerations & Reaction Conditions

While the stoichiometric calculations provide theoretical yields, real-world reactions often involve:

- Side reactions and by-product formation.
- Incomplete reactions due to kinetic factors.
- Catalyst presence (e.g., $FeCl_3$), which significantly increases reaction rate and yield.
- Reaction temperature and solvent effects.
- Purity of reactants and handling procedures.

In controlled laboratory or industrial settings, the actual yield may be somewhat lower than the theoretical due to these factors.

Side Reactions and By-products

Although the primary reaction is the substitution of a hydrogen atom on benzene by chlorine, other pathways may occur:

- Polyhalogenation: Multiple substitutions leading to dichlorobenzene or trichlorobenzene.

- Polymerization or polymer formation under certain conditions.
- Unreacted chlorine may remain if excess is used or if reaction conditions are suboptimal.

However, under typical conditions (with appropriate catalysts and temperature), monosubstitution dominates.

Environmental and Safety Considerations

Handling chlorine gas and chlorinated aromatic compounds necessitates rigorous safety protocols:

- Chlorine gas is toxic, corrosive, and environmentally hazardous.
- Proper containment, ventilation, and protective equipment are essential.
- Waste management must prevent environmental contamination.
- Reaction processes should adhere to safety standards to prevent leaks or accidental releases.

Summary & Final Remarks

- The reaction between 45 grams of chlorine and benzene proceeds with benzene as the limiting reactant.
- The maximum theoretical yield of chlorobenzene is approximately 64.88 grams.
- The molar ratio of 1:1 between Cl_2 and C_6H_6 is fundamental for calculations.
- Practical yields depend on reaction conditions, catalysts, and purity.
- Understanding limiting reactants enables efficient resource utilization and process optimization.

This comprehensive analysis underscores the importance of stoichiometry, reaction mechanisms, and practical considerations in aromatic halogenation, providing a detailed framework for students, chemists, and industrial practitioners alike.

In conclusion, identifying benzene as the limiting reactant in this reaction not only guides the calculation of maximum product yield but also informs process control and efficiency in chemical manufacturing.

C 45 G C H React With 45 G Cl According To The Equation Cl C6h6 C6h5cl Hci What Is The Limiting

C 45 G C H React With 45 G Cl According To The Equation Cl C6h6 C6h5cl Hci What Is The Limiting

Related Articles

- 5. 3 By Convention, A Cache Is Named According To The Amount Of Data It Contains (i. E. , A 4 KiB Cache
- Which Of The Following Statements Is FALSE?Group Of Answer ChoicesA) More Often Than Not, Firms Return
- What Material Was Most Commonly Used By The Chinese And Japanese In Their Constructions Of Rudimentary

Back to Home