A 2.538 G Sample Of Iron Combines With Chlorine Gas To Form An Iron Chloride With A Mass Of 7.25 G. What

A 2.538 G Sample Of Iron Combines With Chlorine Gas To Form An Iron Chloride With A Mass Of 7.25 G. What are the chemical implications and calculations that can be derived from this reaction? Understanding the reaction between iron and chlorine gas is fundamental in chemistry, especially when analyzing reaction composition, stoichiometry, and the determination of empirical formulas. This comprehensive guide will walk you through the entire process, from understanding the basic concepts to performing detailed calculations, ensuring clarity for students and enthusiasts alike.

Understanding the Reaction: Iron and Chlorine Gas

The Basics of Iron and Chlorine Reaction

The reaction between iron (Fe) and chlorine gas (Cl_2) typically results in the formation of iron chloride. Depending on the amount of chlorine involved, iron can form different chlorides such as iron(II) chloride ($FeCl_2$) or iron(III) chloride ($FeCl_3$). The general reaction can be summarized as:

- For iron(II) chloride:
$Fe + Cl_2 \rightarrow FeCl_2$

- For iron(III) chloride:
$2Fe + 3Cl_2 \rightarrow 2FeCl_3$

In our scenario, the known initial mass of iron and the resulting mass of the compound help us deduce which chloride is formed and the stoichiometry involved.

Key Data and Objective

Given Data:

- Mass of iron sample: 2.538 grams
- Mass of resulting iron chloride: 7.25 grams

Objective:

1. Determine the mass of chlorine that combined with iron.
2. Find the empirical formula of the iron chloride formed.
3. Understand the stoichiometry of the reaction involved.

Step 1: Calculating the Mass of Chlorine Used

Determine Chlorine Mass

The mass of chlorine gas that reacted with iron is simply the difference between the total mass of the product and the initial mass of iron:

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Mass of Cl₂ = Mass of iron chloride product - Mass of iron
= 7.25 g - 2.538 g
= 4.712 g
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This calculation indicates that 4.712 grams of chlorine gas reacted with the iron sample.

Step 2: Calculating Moles of Iron and Chlorine

Atomic and Molecular Masses:

- Iron (Fe): approximately 55.85 g/mol
- Chlorine (Cl): approximately 35.45 g/mol

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

Moles of Iron:

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Moles of Fe = Mass of Fe / Atomic mass of Fe
= 2.538 g / 55.85 g/mol
≈ 0.0454 mol
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Moles of Chlorine Gas (Cl_2):

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Moles of Cl₂ = Mass of Cl₂ / Molar mass of Cl₂
= 4.712 g / 70.90 g/mol
≈ 0.06645 mol
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Step 3: Determining the Empirical Formula of the Iron Chloride

Calculating the Ratio of Moles

To find the empirical formula, we need the simplest whole-number ratio of moles of Fe to Cl:

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Ratio of Fe to Cl₂ = 0.0454 mol : 0.06645 mol
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Divide both by the smaller number (0.0454 mol):

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Fe: 0.0454 / 0.0454 = 1
Cl₂: 0.06645 / 0.0454 ≈ 1.464
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Since 1.464 is close to 1.5, multiply both ratios by 2 to obtain whole numbers:

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Fe: 1 × 2 = 2
Cl₂: 1.464 × 2 ≈ 2.928 ≈ 3
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The ratio suggests approximately 2 moles of Fe to 3 moles of Cl atoms (since each Cl_2 molecule contains two Cl atoms):

- 2 Fe atoms
- 3 Cl_2 molecules (which contain 6 Cl atoms)

Thus, the empirical formula is likely Fe_2Cl_3.

Step 4: Confirming the Empirical Formula

Calculating Molar Mass of Fe_2Cl_3

Molar mass of Fe_2Cl_3 = (2 × 55.85) + (3 × 35.45)
= 111.70 + 106.35
= 218.05 g/mol

Mass of Fe_2Cl_3 Based on Moles:

Mass = Moles × Molar mass
= (Number of moles of Fe) × (Molar mass of Fe_2Cl_3)
= 0.0454 mol × 218.05 g/mol
≈ 9.89 g

However, the total mass of the product is only 7.25 g, which indicates that the empirical formula may be $FeCl_3$ (iron(III) chloride). Let's verify with $FeCl_3$.

Step 5: Evaluating the Correct Formula

Calculating Molar Mass of $FeCl_3$:

$FeCl_3$: (55.85) + (3 × 35.45) = 55.85 + 106.35 = 162.20 g/mol

Mass based on moles of Fe (0.0454 mol): 0.0454 mol × 162.20 g/mol ≈ 7.36 g

This is very close to the observed total mass (7.25 g), considering minor rounding errors. Given this, the empirical formula is more consistent with $FeCl_3$ (iron(III) chloride).

Step 6: Final Conclusions and Implications

Summary of Findings:

- The reaction involves approximately 2.538 g of iron reacting with about 4.712 g of chlorine gas.
- The molar ratio suggests the formation of iron(III) chloride, $FeCl_3$.
- The empirical formula determined is $FeCl_3$, based on stoichiometry and mass calculations.

Understanding the Reaction:

The reaction between iron and chlorine gas results in the formation of iron(III) chloride, a compound with significant industrial and chemical importance. This process exemplifies how stoichiometry allows chemists to determine the composition and formulas of compounds based on mass data.

Additional Considerations and Practical Applications

Industrial Production of Iron Chloride

Iron chlorides, especially $FeCl_3$, are widely used in water treatment, as mordants in dyeing, and in the manufacturing of electronics. Understanding the precise stoichiometry helps optimize production processes and ensures purity.

Safety and Handling

Handling chlorine gas and iron chlorides requires proper safety precautions, including working in well-ventilated areas, using protective equipment, and understanding chemical hazards.

Further Analytical Techniques

Laboratory methods such as spectroscopy, titration, and X-ray diffraction can confirm the empirical and molecular formulas of such compounds, supplementing stoichiometric calculations.

Conclusion

A thorough analysis of the reaction between a 2.538 g sample of iron and chlorine gas reveals that approximately 4.712 g of chlorine gas reacts with the iron to produce iron(III) chloride, $FeCl_3$. The calculations demonstrate the importance of stoichiometry in determining chemical formulas and understanding reaction mechanisms. Such knowledge is vital in fields ranging from industrial chemistry to materials science, showcasing the practical significance of fundamental chemical principles.

Keywords: iron chloride, $FeCl_3$, stoichiometry, chemical reaction, empirical formula, chlorine gas, mass calculations, chemical analysis, industrial chemistry

Frequently Asked Questions

What is the mass of iron that reacted in the formation of iron chloride?

The mass of iron that reacted is 2.538 grams.

What is the total mass of the iron chloride produced?

The total mass of iron chloride formed is 7.25 grams.

How do you determine the mass of chlorine gas that reacted with iron?

Subtract the mass of iron from the total mass of iron chloride: 7.25 g - 2.538 g = 4.712 g of chlorine gas.

What is the molar mass of iron (Fe) and chlorine (Cl)?

The molar mass of Fe is approximately 55.85 g/mol, and Cl is approximately 35.45 g/mol.

How can you find the empirical formula of the iron chloride formed?

Calculate moles of Fe and Cl from their masses, then find the simplest ratio to determine the empirical formula.

What is the number of moles of iron used in the reaction?

Number of moles of Fe = 2.538 g / 55.85 g/mol ≈ 0.0454 mol.

What is the number of moles of chlorine gas that reacted?

Number of moles of Cl = 4.712 g / 35.45 g/mol ≈ 0.133 mol.

Based on the moles calculated, what is the ratio of Cl to Fe in the compound?

The ratio is approximately 0.133 mol Cl / 0.0454 mol Fe ≈ 2.93, close to 3, suggesting a formula of $FeCl_3$.

What is the likely chemical formula of the iron chloride formed in this reaction?

The probable formula is $FeCl_3$, indicating iron is in the +3 oxidation state.

How does this experiment illustrate stoichiometry principles?

It demonstrates calculating reactant and product masses, determining molar ratios, and deriving empirical formulas based on mass and mole data.

Additional Resources

A 2.538 G Sample Of Iron Combines With Chlorine Gas To Form An Iron Chloride With A Mass Of 7.25 G. What

Understanding chemical reactions, especially those involving elements like iron and chlorine, is fundamental in chemistry. The problem statement presents a classic stoichiometry scenario where a sample of iron reacts with chlorine gas to produce an iron chloride compound. This type of problem is often encountered in analytical chemistry, inorganic chemistry, and during laboratory experiments designed to understand the relationships between reactants and products. In this detailed review, we will explore the problem, analyze the data, and discuss the concepts involved, including molar

calculations, reaction mechanisms, and practical applications.

Breaking Down the Problem

The initial step in analyzing this problem is understanding what information is given and what is required.

- Given Data:
- Mass of iron sample: 2.538 grams
- Final mass of iron chloride formed: 7.25 grams
- The reaction involves iron (Fe) and chlorine gas (Cl_2)

- What is asked:
- Likely, the problem aims to find the amount (moles) of iron and chlorine involved,
- The empirical or molecular formula of the iron chloride,
- Or perhaps the percentage composition or the reaction's stoichiometry.

Since the question snippet is incomplete, the typical goal in such problems is to determine the formula of the iron chloride formed or to analyze the mole ratios involved.

Understanding the Chemical Reaction

The Reaction Between Iron and Chlorine Gas

The reaction between iron and chlorine gas is a classic synthesis reaction:

$$\text{Fe} + \text{Cl}_2 \rightarrow \text{FeCl}_x$$

where x indicates the number of chlorine atoms per iron atom in the compound. The common iron chlorides are:

- Iron(II) chloride: $FeCl_2$
- Iron(III) chloride: $FeCl_3$

Determining the Formula of Iron Chloride

Given the initial mass of iron and the total mass of iron chloride, we can find:

- The mass of chlorine incorporated into the compound,
- The moles of iron and chlorine involved,
- The empirical formula of the compound.

Calculations and Analysis

Mass of Chlorine in the Compound

The total mass of iron chloride:

$$\text{Mass of FeCl}_x = 7.25\, \text{g}$$

Mass of iron initially:

$$\text{Mass of Fe} = 2.538\, \text{g}$$

Mass of chlorine:

$$\text{Mass of Cl} = 7.25\, \text{g} - 2.538\, \text{g} = 4.712\, \text{g}$$

This calculation assumes complete reaction and no other products, which is standard for such stoichiometry problems.

Moles of Iron and Chlorine

Using atomic masses:

- Iron (Fe): approximately 55.845 g/mol
- Chlorine (Cl): approximately 35.45 g/mol (per atom), Cl_2: 70.90 g/mol

Calculating moles:

- Moles of Fe:

$$n_\text{Fe} = \frac{2.538\, \text{g}}{55.845\, \text{g/mol}} \approx 0.0454\, \text{mol}$$

- Moles of Cl:

$$n_\text{Cl} = \frac{4.712\, \text{g}}{35.45\, \text{g/mol}} \approx 0.133\, \text{mol}$$

Since chlorine reacts as Cl_2, the moles of Cl_2:

$$ n_{\text{Cl}_2} = \frac{0.133\, \text{mol}}{2} \approx 0.0665\, \text{mol} $$

Determining the Empirical Formula

The molar ratio of Cl to Fe:

$$ \frac{n_\text{Cl}}{n_\text{Fe}} \approx \frac{0.133}{0.0454} \approx 2.93 $$

This is very close to 3, indicating a molar ratio of Cl to Fe of approximately 3:1, which suggests the compound is likely $FeCl_3$.

Conclusion:

The empirical formula of the iron chloride formed in this reaction is $FeCl_3$.

Features and Significance of Iron Chlorides

Properties of $FeCl_3$

- Appearance: Dark brown or reddish-brown crystalline solid.
- Solubility: Highly soluble in water, forming acidic solutions.
- Uses:
- As a mordant in textile dyeing.
- In water treatment as a coagulant.
- As a catalyst in organic synthesis.
- Features:
- Hygroscopic, tends to absorb moisture from the air.
- The compound can exist in hydrated forms (e.g., $FeCl_3 \cdot 6H_2O$).

Properties of $FeCl_2$ (if relevant)

- Appearance: Pale greenish or yellowish solid.
- Uses:
- In steel manufacturing for corrosion inhibition.
- As a reducing agent.
- Features:
- Less stable than $FeCl_3$.

- Tends to oxidize to $FeCl_3$ when exposed to air.

Practical Applications and Implications

Understanding the stoichiometry of iron and chlorine reactions is essential for various industrial processes, environmental chemistry, and laboratory synthesis.

- Industrial Production: Manufacturing iron chlorides for use in water treatment or as catalysts.
- Environmental Considerations: Proper handling of chlorine and iron compounds to prevent environmental contamination.
- Laboratory Synthesis: Preparing pure samples of $FeCl_3$ for research or educational demonstrations.

Pros and Cons of Handling Iron Chlorides

Pros:

- Versatility: Used in multiple industrial and laboratory applications.
- Reactivity: Useful as reagents and catalysts.
- Availability: Easily synthesized via straightforward reactions.

Cons:

- Corrosiveness: Can be highly corrosive, posing safety hazards.
- Hygroscopic Nature: Absorbs moisture, complicating storage.
- Environmental Impact: Potential pollution if improperly disposed of.

Conclusion

This detailed analysis of the reaction between a 2.538 g sample of iron and chlorine gas illustrates fundamental principles of stoichiometry, chemical formulas, and practical chemistry. By calculating the molar ratios, we deduced that the product is most likely $FeCl_3$, a common and important iron chloride. Understanding these reactions highlights the significance of precise measurements, molar calculations, and chemical intuition in both academic and industrial contexts. The properties, applications, and handling considerations of iron chlorides further emphasize their importance and the need for careful management in their use. Overall, this problem serves as an excellent example of

how quantitative analysis can reveal molecular details and guide practical applications in chemistry.

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