Determine The Mass Of Lead Chloride Precipitated When 5g Of Sodium Chloride Solution Reacts With Lead

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Understanding the chemical interactions between different elements and compounds is fundamental in chemistry. One such reaction involves the formation of lead chloride when sodium chloride reacts with lead. In this article, we will explore the detailed steps to calculate the mass of lead chloride precipitated when a specified amount of sodium chloride solution reacts with lead. This process encompasses understanding chemical equations, molar calculations, and stoichiometry principles, providing a comprehensive approach to solving such problems.

Introduction to the Reaction

Background of the Chemical Reaction

The reaction between sodium chloride (NaCl) and lead (Pb) involves the formation of lead chloride ($PbCl_2$), a precipitate, through a double displacement reaction. When a solution containing sodium chloride interacts with lead metal, lead chloride forms as a solid precipitate, often used in qualitative analysis and various industrial applications.

The overall reaction can be represented as:
$$\mathrm{Pb\ (s) + 2NaCl\ (aq) \rightarrow PbCl_2\ (s) + 2Na\ (aq)}$$

However, in typical laboratory scenarios, the sodium chloride solution is in excess, and lead metal is added to precipitate lead chloride.

Understanding the Chemical Equation

Balanced Chemical Equation

The key to solving this problem lies in the balanced chemical equation:

$$ \mathrm{Pb (s) + 2NaCl (aq) \rightarrow PbCl_2 (s) + 2Na (aq)} $$

This indicates that one mole of lead reacts with two moles of sodium chloride to produce one mole of lead chloride precipitate.

Implications of the Reaction

- The mole ratio of lead to lead chloride is 1:1.
- The sodium chloride acts as a source of chloride ions, which combine with lead ions to form lead chloride.
- The amount of sodium chloride present determines the maximum amount of lead chloride that can be precipitated, assuming excess lead is available.

Calculating Moles of Sodium Chloride

Step 1: Determine the Molar Mass of Sodium Chloride

The molar mass of NaCl is calculated as:
- Sodium (Na): 22.99 g/mol
- Chlorine (Cl): 35.45 g/mol

$$
\text{Molar mass of NaCl} = 22.99 + 35.45 = 58.44\, \text{g/mol}
$$

Step 2: Convert the Given Mass to Moles

Given mass of sodium chloride solution:
- 5 grams

Calculate the number of moles:
$$
\text{Moles of NaCl} = \frac{\text{Mass}}{\text{Molar mass}} = \frac{5\, \text{g}}{58.44\, \text{g/mol}} \approx 0.0856\, \text{mol}
$$

Note: This calculation assumes that the 5g represents pure sodium chloride. If the solution is dilute, the actual mass of NaCl dissolved would be less, but for this problem, we take it as pure.

Determining the Limiting Reactant and Reaction Conditions

Is Lead or Sodium Chloride in Excess?

- The question states that sodium chloride solution reacts with lead. To proceed, we need to assume an amount of lead available or specify the mass of lead used.
- For simplicity, let's assume excess lead metal is present, meaning sodium chloride is the limiting reactant.

Assumption for the Calculation

- The sodium chloride is the limiting reactant.
- The amount of lead is sufficient to react with all the chloride ions present.

Calculating the Moles of Lead Chloride Formed

Step 1: Use the Mole Ratio from the Balanced Equation

From the balanced equation:
- 2 moles of NaCl produce 1 mole of $PbCl_2$.

Therefore:
$$
\text{Moles of PbCl}_2 = \frac{\text{Moles of NaCl}}{2} = \frac{0.0856}{2} \approx 0.0428\, \text{mol}
$$

Step 2: Confirm the Precipitate Formation

- Assuming full reaction, all chloride ions from sodium chloride are used to precipitate lead chloride.
- The moles of lead chloride formed are equal to 0.0428 mol.

Calculating the Mass of Lead Chloride Precipitated

Step 1: Molar Mass of Lead Chloride

Calculate the molar mass of $PbCl_2$:

- Lead (Pb): 207.2 g/mol
- Chlorine (Cl): 35.45 g/mol

$$
\text{Molar mass of PbCl}_2 = 207.2 + 2 \times 35.45 = 207.2 + 70.9 = 278.1\, \text{g/mol}
$$

Step 2: Convert Moles to Mass

$$
\text{Mass of PbCl}_2 = \text{Moles} \times \text{Molar mass} = 0.0428 \times 278.1 \approx 11.89\, \text{g}
$$

Result: Approximately 11.89 grams of lead chloride precipitate is formed when 5 grams of sodium chloride solution reacts with excess lead.

Additional Considerations and Real-World Factors

Purity of the Sodium Chloride Solution

- The calculation assumes pure NaCl. In practice, solutions contain impurities which may affect the actual amount of precipitate formed.

Solubility of Lead Chloride

- Lead chloride has limited solubility in water (~1.6 g per 100 mL at room temperature).
- The calculation presumes complete precipitation, but in reality, some lead chloride remains dissolved unless the solution is saturated.

Reaction Conditions

- Temperature, agitation, and presence of other ions can influence the yield.
- The actual yield may be less due to incomplete reaction or losses during filtration.

Summary of the Calculation Process

1. Calculate the molar mass of sodium chloride (NaCl).
2. Convert the given mass of NaCl to moles.
3. Use the stoichiometric ratio from the balanced equation to find moles of lead chloride formed.
4. Calculate the molar mass of lead chloride ($PbCl_2$).
5. Multiply the moles of $PbCl_2$ by its molar mass to find the precipitate's mass.

Final Answer: Approximately 11.89 grams of lead chloride are precipitated under the given conditions.

Conclusion

Calculating the mass of lead chloride precipitated from a reaction involving sodium chloride and lead requires a thorough understanding of chemical equations, molar relationships, and stoichiometry principles. Starting from the known mass of sodium chloride, we determine the number of moles, relate it to the amount of lead chloride formed via the mole ratio, and then convert this to mass. While theoretical calculations provide valuable insights, actual experimental yields may vary due to practical factors such as solubility and reaction completeness. Nonetheless, this systematic approach offers a reliable method to estimate precipitate quantities in chemical reactions, essential for laboratory planning, industrial processes, and academic studies.

Frequently Asked Questions

What is the chemical reaction between sodium chloride and lead nitrate that leads to the formation of lead chloride?

When sodium chloride reacts with lead nitrate, a double displacement reaction occurs, forming lead chloride ($PbCl_2$) as a precipitate and sodium nitrate in solution: $2\ NaCl + Pb(NO_3)_2 \rightarrow PbCl_2\ (s) + 2\ NaNO_3$.

How do you determine the mass of lead chloride precipitated in the reaction?

First, identify the moles of sodium chloride used, then use stoichiometry from the balanced equation to find the moles of lead chloride formed. Finally, convert moles of lead chloride to mass using its molar mass.

Given 5 g of sodium chloride, what is the molar amount of NaCl involved in the reaction?

Number of moles of NaCl = mass / molar mass = 5 g / 58.44 g/mol ≈ 0.0856 mol.

What is the molar mass of lead chloride ($PbCl_2$)?

The molar mass of $PbCl_2$ = 207.2 g/mol (Pb) + 2 × 35.45 g/mol (Cl) = 207.2 + 70.9 = 278.1 g/mol.

How do you calculate the mass of lead chloride precipitated from the moles of sodium chloride?

Since the reaction shows 2 mol NaCl produce 1 mol $PbCl_2$, the moles of $PbCl_2$ formed = 0.0856 mol / 2 ≈ 0.0428 mol. Then, mass of $PbCl_2$ = moles × molar mass = 0.0428 mol × 278.1 g/mol ≈ 11.89 g.

What assumptions are made in calculating the precipitated lead chloride's mass?

Assumptions include complete reaction with no side reactions, all sodium chloride reacts to form lead chloride, and the reaction goes to completion without losses.

What are common sources of error in experimentally determining the mass of lead chloride precipitated?

Errors can arise from incomplete precipitation, impurities in reactants, loss of precipitate during filtration, inaccurate measurements of reactants, or not accounting for side reactions.

Additional Resources

Determine The Mass Of Lead Chloride Precipitated When 5g Of Sodium Chloride Solution Reacts With Lead

Understanding how to determine the mass of lead chloride precipitated in a chemical reaction is fundamental for students and professionals working in chemistry, environmental science, and industrial

applications. The problem involves calculating the amount of lead chloride ($PbCl_2$) formed when a known quantity of sodium chloride (NaCl) solution reacts with lead (Pb). This type of calculation combines knowledge of stoichiometry, molar relationships, and solution concentrations, making it a valuable exercise in quantitative analysis.

Introduction

Chemical reactions often involve the formation of precipitates—insoluble compounds that separate from a solution when certain reactants combine. In this scenario, sodium chloride reacts with lead to produce lead chloride, a white precipitate. The key challenge is to determine how much lead chloride is formed when a specific amount of sodium chloride solution is introduced to lead metal or lead ion solution.

This guide aims to provide a comprehensive step-by-step approach to solving such problems, including understanding the reaction, calculating molar quantities, and applying stoichiometric relationships to find the mass of the precipitate.

Understanding the Reaction

The Chemical Equation

The primary reaction involved in precipitating lead chloride is:

$$\text{Pb}^{2+} (aq) + 2 \text{Cl}^- (aq) \rightarrow \text{PbCl}_2 (s)$$

This indicates that lead ions react with chloride ions to form solid lead chloride, which precipitates out of solution.

Context of the Problem

- Given: 5 grams of sodium chloride solution (NaCl solution)
- Goal: Determine the mass of lead chloride precipitated when this NaCl reacts with lead.

Note: The problem assumes that lead is present in a form capable of reacting with chloride ions—either as lead ions in solution or as metallic lead that reacts with chloride ions under certain conditions. For simplicity, we typically assume an aqueous lead ion source, such as lead(II) nitrate or lead acetate, is added to the sodium chloride solution. If the problem states "reacts with lead," it implies either metallic lead reacting with chloride (via a different pathway) or lead ions already present.

Step 1: Clarify the Nature of the Reactants

Case 1: Lead ions already present in solution

If the problem states that sodium chloride solution reacts with lead, it's often assumed that lead ions are already in solution, or that lead metal is reacting with chloride ions under certain conditions. For simplicity, assume:

- The lead source is soluble, e.g., lead(II) nitrate ($Pb(NO_3)_2$).
- The sodium chloride provides chloride ions.

Case 2: Metallic lead reacting directly

Lead metal reacts with chloride ions under specific conditions to produce lead chloride:

\[\text{Pb} (s) + 2 \text{Cl}^- (aq) \rightarrow \text{PbCl}_2 (s) + 2 e^- \]

However, this reaction typically requires an electrochemical context or specific conditions. For the purposes of this calculation, considering the typical scenario, we'll assume lead ions are provided in solution.

Step 2: Calculate Moles of Sodium Chloride

Given 5 grams of NaCl solution, the first step is to find the number of moles of NaCl present.

Step 2.1: Find the molar mass of NaCl

Element	Atomic Mass (g/mol)
Na	22.99
Cl	35.45

Molar mass of NaCl = 22.99 + 35.45 = 58.44 g/mol

Step 2.2: Calculate moles of NaCl

\[
\text{Moles of NaCl} = \frac{\text{Mass of NaCl}}{\text{Molar mass of NaCl}} = \frac{5\,g}{58.44\,g/mol} \approx 0.0856\, \text{mol}
\]

Step 3: Determine the Chloride Ion Concentration

Since NaCl dissociates completely in solution:

$$
\text{NaCl} \rightarrow \text{Na}^+ + \text{Cl}^-
$$

The number of moles of chloride ions (Cl^-) in solution is equal to the moles of NaCl:

$$
\text{Moles of Cl}^- = 0.0856\, \text{mol}
$$

Step 4: Establish the Molar Relationship for Lead Chloride Formation

The balanced chemical equation:

$$
\text{Pb}^{2+} + 2 \text{Cl}^- \rightarrow \text{PbCl}_2
$$

shows that 1 mole of lead ions reacts with 2 moles of chloride ions to produce 1 mole of lead chloride precipitate.

Assumption:

- The lead source provides sufficient lead ions to react with all chloride ions present.
- The limiting reagent here is the chloride ions, which are in excess or sufficient to react with the lead.

Step 5: Calculate the Moles of Lead Chloride Precipitated

Step 5.1: Determine the maximum moles of $PbCl_2$ that can form

Since 2 mol of Cl^- are needed per mol of $PbCl_2$:

$$
\text{Moles of PbCl}_2 = \frac{\text{Moles of Cl}^-}{2} = \frac{0.0856}{2} \approx 0.0428\, \text{mol}
$$

This assumes that lead ions are present in excess, ensuring complete reaction of chloride ions.

Step 6: Calculate the Mass of Lead Chloride Precipitated

Step 6.1: Find the molar mass of $PbCl_2$

Element	Atomic Mass (g/mol)
Pb	207.2
Cl	35.45

Molar mass of $PbCl_2$ = 207.2 + 2(35.45) = 207.2 + 70.9 = 278.1 g/mol

Step 6.2: Compute the mass

$$
\text{Mass of PbCl}_2 = \text{moles} \times \text{molar mass} = 0.0428\, \text{mol} \times 278.1\, g/mol \approx 11.89\, g
$$

Final Answer:

The mass of lead chloride precipitated is approximately 11.89 grams when 5 grams of sodium chloride solution reacts with an excess of lead ions.

Additional Considerations

Factors Influencing the Reaction

- Purity of reactants: Impurities can affect yields.
- Reaction conditions: Temperature, pH, and concentration influence precipitation.
- Limiting reagent: If lead is limiting, the amount of precipitate would be less.
- Stoichiometry accuracy: Ensure molar ratios are correctly applied.

Practical Applications

Understanding such calculations is crucial in industries like:

- Mining: Extracting lead compounds.
- Water treatment: Removing lead ions via precipitation.
- Laboratory analysis: Quantitative determination of metal ions.

Summary

Determining the mass of lead chloride precipitated from a specified amount of sodium chloride solution involves:

- Calculating the moles of chloride ions supplied.
- Applying the molar ratio from the balanced chemical equation.
- Calculating the corresponding moles and mass of lead chloride formed.

This process exemplifies key principles in chemical stoichiometry and solution chemistry, providing a foundation for more complex analytical techniques and industrial processes.

Final Note

Always verify assumptions in real-world scenarios, and consider experimental conditions that might alter theoretical yields. Proper lab techniques and calculations ensure accurate analysis and understanding of chemical reactions, such as the precipitation of lead chloride from chloride sources.

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