(Mole-Mole) Balance The Reaction Below And Determine The Number Of Moles Of Solid Lead Formed If 4.50

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Understanding chemical reactions and their stoichiometric relationships is fundamental in chemistry. When dealing with reactions involving solids and gases, accurately balancing the chemical equation is essential for determining the quantities of reactants and products involved. In this article, we will explore how to balance a chemical reaction at the mole level, specifically focusing on the reaction that produces solid lead (Pb). Moreover, we will determine the number of moles of solid lead formed when a given amount of reactant is used, exemplified by a scenario involving 4.50 moles of a reactant.

Introduction to Mole-Mole Balancing and Stoichiometry

What is Mole-Mole Balancing?

Mole-mole balancing involves adjusting a chemical equation so that the number of moles of each element or compound on the reactant side equals the number on the product side. This process ensures that the law of conservation of mass is obeyed, meaning matter is neither created nor destroyed during the reaction.

Why Is Balancing Important?

- Accurate Quantitative Analysis: It allows chemists to predict how much product can be formed from given amounts of reactants.
- Stoichiometry Calculations: Helps in calculating the theoretical yields and limiting reactants.
- Chemical Safety and Efficiency: Proper balancing ensures reactions are conducted safely and efficiently without excess waste.

Understanding the Reaction: Lead and Its Compounds

Before balancing, we need the specific chemical reaction. Let's consider a common reaction involving lead:

Reaction:
$$\mathrm{Pb^{2+} (aq) + 2\, e^- \rightarrow Pb (s)}$$

However, for a more comprehensive example, suppose we are dealing with a reaction where lead nitrate reacts with a reducing agent, such as:

$$\mathrm{Pb(NO_3)_2 (aq) + \text{Reducing Agent} \rightarrow Pb (s) + \text{Oxidized products}}$$

But for simplicity, assume the reaction involves the reduction of lead ions to solid lead:

$$\mathrm{Pb^{2+} (aq) + 2\, e^- \rightarrow Pb (s)}$$

In practice, reactions often involve compounds, and the balancing involves the entire molecular equation.

Step-by-Step Process to Balance the Reaction

1. Write the Unbalanced Equation

Suppose we are considering the reduction of lead nitrate by a suitable reducing agent (for example, zinc). The overall reaction might look like:

$$\mathrm{Pb(NO_3)_2 (aq) + Zn (s) \rightarrow Pb (s) + Zn(NO_3)_2 (aq)}$$

This is a typical single displacement reaction. Let's ensure the reaction is balanced.

2. Balance the Chemical Equation

- Lead (Pb): 1 atom on both sides.
- Nitrate (NO_3): 2 nitrates on the left (in lead nitrate), and 2 nitrates on the right (in zinc nitrate).
- Zinc (Zn): 1 atom on both sides.

Thus, the balanced equation is:

$$ \mathrm{Pb(NO_3)_2 (aq) + Zn (s) \rightarrow Pb (s) + Zn(NO_3)_2 (aq)} $$

This equation is already balanced with a 1:1 molar ratio.

Calculating the Moles of Lead Formed

Now, suppose you start with 4.50 moles of lead nitrate ($\mathrm{Pb(NO_3)_2}$). How many moles of solid lead (Pb) will be formed?

3. Using the Mole Ratio

From the balanced reaction:

$$ 1\, \text{mol} \, \mathrm{Pb(NO_3)_2} \rightarrow 1\, \text{mol} \, \mathrm{Pb} $$

The mole ratio between lead nitrate and solid lead is 1:1.

4. Calculation

Given:
- Moles of $\mathrm{Pb(NO_3)_2}$ = 4.50 mol

Using the ratio:
$$ \text{Moles of } \mathrm{Pb} = \text{Moles of } \mathrm{Pb(NO_3)_2} \times \frac{1\, \text{mol} \, \mathrm{Pb}}{1\, \text{mol} \, \mathrm{Pb(NO_3)_2}} $$

Therefore:
$$ \text{Moles of } \mathrm{Pb} = 4.50\, \text{mol} $$

Result: 4.50 moles of solid lead will be formed when 4.50 moles of lead nitrate react completely.

Factors Affecting the Reaction and Yield

While the stoichiometric calculations assume ideal conditions, real-world reactions can be affected by several factors:

1. Limiting Reactant

If other reactants are in different proportions, the actual amount of lead formed depends on the limiting reactant.

2. Reaction Conditions

Temperature, pressure, and catalysts can influence reaction rates and yields.

3. Purity of Reactants

Impurities may reduce the efficiency of the reaction, leading to less product formation.

Additional Considerations in Molar Calculations

1. Converting Mass to Moles

If you start with a mass of lead nitrate, convert it to moles using molar mass:

$$\text{Moles} = \frac{\text{Mass}}{\text{Molar mass}}$$

2. Molar Mass of Lead Nitrate ($\mathrm{Pb(NO_3)_2}$)

Calculate as:
- Pb: 207.2 g/mol
- N: 14.0 g/mol × 2 = 28.0 g/mol
- O: 16.0 g/mol × 6 = 96.0 g/mol

Total molar mass:

$$207.2 + 28.0 + 96.0 = 331.2\, \text{g/mol}$$

3. Practical Example

Suppose you have 150 g of lead nitrate:

$$\text{Moles} = \frac{150\, \text{g}}{331.2\, \text{g/mol}} \approx 0.453\, \text{mol}$$

Using the mole ratio:

$$\text{Moles of Pb} = 0.453\, \text{mol}$$

Summary and Practical Applications

- Balancing chemical equations at the mole level is crucial for accurate stoichiometric calculations.
- In reactions involving lead, understanding the mole ratios allows for predicting product yields.
- For the example given, starting with 4.50 moles of lead nitrate results in the formation of 4.50 moles of solid lead, assuming complete reaction and ideal conditions.
- Real-world applications include manufacturing, waste management, and analytical chemistry, where precise calculations are necessary.

Conclusion

Mastering mole-mole balancing and stoichiometry calculations enables chemists and students to predict the outcomes of chemical reactions accurately. Whether you're working in a lab or solving academic problems, understanding these principles ensures you can determine the amount of product formed from a given amount of reactant. In the specific case of lead nitrate reacting to form solid lead, balancing the reaction and calculating the molar quantities are straightforward once the correct ratios are established. With practice, these calculations become an invaluable part of your chemistry toolkit.

Keywords for SEO Optimization:
- Mole-mole balancing
- Stoichiometry
- Chemical reaction balancing
- Lead nitrate reaction
- Moles of lead formed
- Predicting product yield
- Limiting reactant
- Molar mass calculation
- Chemistry calculations
- Solid lead formation

Frequently Asked Questions

What is the balanced chemical equation for the reaction involving molybdenum (Mo) and lead (Pb)?

The balanced reaction is $3Mo + 2PbCl_2 \rightarrow 3MoCl_2 + 2Pb$.

How do you determine the number of moles of solid lead formed from 4.50 moles of a reactant?

Use the stoichiometric ratios from the balanced equation to convert the given moles of reactant to moles of lead formed.

What is the molar ratio between molybdenum and lead in this reaction?

The molar ratio is 3 mol Mo : 2 mol Pb.

If 4.50 moles of molybdenum react, how many moles of lead are produced?

Using the ratio 3:2, (4.50 mol Mo) × (2 mol Pb / 3 mol Mo) = 3.00 mol Pb.

Does the initial amount of reactant determine the maximum amount of solid lead formed?

Yes, the limiting reactant determines the maximum moles of lead that can be produced.

What additional information is needed to determine the exact mass of lead formed?

The molar mass of lead (Pb), which is approximately 207.2 g/mol, is needed to convert moles to grams.

How do you verify if molybdenum is the limiting reactant in the reaction?

Compare the amount of reactants available and use stoichiometry to see which reactant is completely consumed first.

What are key steps in balancing a chemical reaction for mole calculations?

Identify the reactants and products, write the unbalanced equation, adjust coefficients to balance atoms, and then use the balanced equation for mole ratios.

What is the significance of balancing the reaction in mole calculations?

Balancing ensures the conservation of mass, allowing accurate stoichiometric conversions between reactants and products.

Additional Resources

Mole-Mole: Balancing the Reaction and Determining the Moles of Solid Lead Formed

In the realm of chemistry, understanding how to accurately balance chemical reactions and determine the quantities of products formed is fundamental. Among the many concepts chemists employ, the mole-mole relationship is a cornerstone for quantifying reactants and products in chemical equations. This article delves into the process of balancing a specific reaction involving lead and other substances, and then utilizing stoichiometry to calculate the number of moles of solid lead produced when a given amount of reactant is involved.

Understanding the Concept of Mole-Mole Relationships

What Is a Mole?

A mole is a fundamental unit in chemistry representing a specific number of particles. Precisely, one mole equals Avogadro’s number, approximately 6.022 x 10^{23} entities (atoms, molecules, ions, etc.). This concept allows chemists to relate macroscopic quantities of substances to their microscopic constituents.

Why Is Mole-Mole Relationship Important?

The mole-mole relationship is crucial because it provides a direct link between the quantities of reactants and products involved in a chemical reaction. It enables chemists to:

- Convert between mass, moles, and number of particles.
- Determine the amount of product formed from a known quantity of reactant.
- Balance chemical equations to reflect the conservation of mass.

Basic Principles of Mole-Mole Calculations

The core principle is the stoichiometric coefficient from the balanced chemical equation, which indicates the molar ratio of reactants and products involved. For example, if the balanced equation shows 1 mole of substance A reacts with 2 moles of substance B, then these ratios can be used to determine the amount of each substance involved in the reaction.

Balancing the Chemical Reaction

Identifying the Reaction Components

Suppose we are dealing with a typical reaction involving lead, such as:

$$ \text{Pb (s)} + \text{HNO}_3 \text{(aq)} \rightarrow \text{Pb(NO}_3)_2 \text{(aq)} + \text{H}_2 \text{(g)} $$

However, for the purpose of a comprehensive analysis, let's consider a more specific reaction often encountered in lead chemistry:

$$ \text{Pb (s)} + 2 \text{HNO}_3 \text{(aq)} \rightarrow \text{Pb(NO}_3)_2 \text{(aq)} + \text{H}_2 \text{(g)} $$

This reaction depicts lead reacting with nitric acid to produce lead nitrate and hydrogen gas.

Steps to Balance the Equation

Balancing involves ensuring the number of atoms for each element is the same on both sides.

1. Write the unbalanced equation:
$$ \text{Pb} + \text{HNO}_3 \rightarrow \text{Pb(NO}_3)_2 + \text{H}_2 $$

2. Identify the elements and their counts:
- Lead (Pb): 1 on both sides
- Nitrogen (N): 1 on the reactant side, 2 on the product side
- Hydrogen (H): 1 on reactant side (in HNO_3), 2 in H_2
- Oxygen (O): 3 in HNO_3, 6 in $Pb(NO_3)_2$

3. Adjust coefficients to balance nitrogen:
Since there are 2 nitrates in the product, the reactant side should have 2 HNO_3 molecules:
$$
\text{Pb} + 2 \text{HNO}_3 \rightarrow \text{Pb(NO}_3)_2 + \text{H}_2
$$

4. Balance hydrogen:
Now, hydrogen atoms are 2 on the reactant side (in 2 HNO_3) and 2 in H_2, so hydrogen is balanced.

5. Verify oxygen atoms:
- Reactants: 2 HNO_3 molecules = 2 x 3 = 6 oxygen atoms

- Products: $Pb(NO_3)_2$ contains 2 nitrates, each with 3 oxygen atoms, totaling 6 oxygen atoms
Oxygen atoms are balanced.

6. Final balanced equation:

$$ \text{Pb} + 2 \text{HNO}_3 \rightarrow \text{Pb(NO}_3)_2 + \text{H}_2 $$

This balanced equation indicates that 1 mole of lead reacts with 2 moles of nitric acid to produce 1 mole of lead nitrate and 1 mole of hydrogen gas.

Calculating Moles of Lead Formed or Consumed

Understanding the Given Data

Suppose we are told that 4.50 grams of lead are involved in the reaction. Our goal is to determine the number of moles of solid lead formed or reacted and, in the case of a reaction, how much product is produced.

Conversion from Mass to Moles

The fundamental step is converting the given mass to moles using the molar mass of lead.

- Molar mass of lead (Pb): approximately 207.2 g/mol

$$
\text{Moles of Pb} = \frac{\text{Mass of Pb}}{\text{Molar mass of Pb}} = \frac{4.50\, \text{g}}{207.2\, \text{g/mol}} \approx 0.02174\, \text{mol}
$$

This calculation implies that 0.02174 mol of lead is involved in the reaction.

Applying Stoichiometry to Determine the Moles of Lead Formed

Using the Balanced Equation

From the balanced equation:

$$ \text{Pb} + 2 \text{HNO}_3 \rightarrow \text{Pb(NO}_3)_2 + \text{H}_2 $$

- The molar ratio of lead to lead nitrate is 1:1.
- The molar ratio of lead to hydrogen gas is also 1:1.

Assuming complete reaction and that lead is the limiting reactant, the moles of lead nitrate formed will be equal to the moles of lead reacted:

$$
\text{Moles of Pb(NO}_3)_2 \text{ formed} = 0.02174\, \text{mol}
$$

Similarly, the moles of hydrogen gas produced will also be 0.02174 mol.

Calculating the Mass of Lead Nitrate Formed

To find the mass of lead nitrate formed:

- Molar mass of $Pb(NO_3)_2$:

$$
\text{Pb} = 207.2\, \text{g/mol}
$$
$$
\text{N} = 14.01\, \text{g/mol}
$$
$$
\text{O} = 16.00\, \text{g/mol}
$$

Calculating:

$$
\text{Pb(NO}_3)_2 = 207.2 + 2 \times (14.01 + 3 \times 16.00) = 207.2 + 2 \times (14.01 + 48.00) = 207.2 + 2 \times 62.01 = 207.2 + 124.02 = 331.22\, \text{g/mol}
$$

Mass of lead nitrate:

$$
\text{Mass} = \text{moles} \times \text{molar mass} = 0.02174 \times 331.22 \approx 7.20\, \text{g}
$$

Thus, approximately 7.20 grams of lead nitrate can be expected from 4.50

grams of lead reacting completely.

Determining the Number of Moles of Solid Lead Formed

Reversibility and Reaction Conditions

In most practical scenarios, lead reacts with acids to form soluble lead salts, not solid lead. However, in a different context, such as a reduction process or a reaction where lead is precipitated out or formed as a solid, the calculation would differ.

Suppose, in a hypothetical or reverse process, a certain amount of lead is recovered as a solid:

- If the reaction involved reduction or deposition of lead from a solution, the same molar ratios would apply.
- The number of moles of solid lead formed would be equal to the number of moles reacted, assuming 100% efficiency.

Given the initial data:

$$
\boxed{\text{4.50 grams of lead}} \rightarrow \text{Number of moles} \approx 0.02174\, \text{mol}
$$

If this lead is entirely precipitated or recovered as a solid in the process, then the number of moles of solid lead formed is approximately 0.02174 mol.

In summary:

Quantity	Value
Mass of lead	4.50 g
Moles of lead	~0.02174 mol
Moles of lead nitrate formed	~0.02174 mol
Mass of lead nitrate formed	~7.20 g

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