Chemistry Stoichiometry Key

Chemical Reaction Stoichiometry Key

1. Propane (C_3H_8) undergoes combustion in air according to the following balanced equation:

$$C_3H_8(g) + 5\,O_2(g) \rightarrow 3\,CO_2(g) + 4\,H_2O(g)$$

a. How many molecules of CO_2 will be formed when 25 molecules of C_3H_8 react?

$$25\ molecules\ C_3H_8 \times \frac{3\ molecules\ CO_2}{1\ molecule\ C_3H_8} = 75\ molecules\ C_3H_8$$

b. How many moles of oxygen are needed to react with 12.5 mol of C_3H_8?

$$12.5\ mol\ C_3H_8 \times \frac{5\ mol\ O_2}{1\ mol\ C_3H_8} = 62.5\ mol\ O_2$$

c. How many grams of C_3H_8 react with 500.0 grams of oxygen?

$$\mathbf{500.0}\ g\ O_2 \times \frac{1\ mol\ O_2}{32.00\ g\ O_2} \times \frac{1\ mol\ C_3H_8}{5\ mol\ O_2} \times \frac{44.097\ g\ C_3H_8}{1\ mol\ C_3H_8} = \mathbf{137.8}03 = 137.8\ g\ C_3H_8$$

d. If a cylinder of propane contains 1.00 kg of C_3H_8, how many grams of CO_2 are formed when it burns?

$$\mathbf{1.00}\ kg\ C_3H_8 \times \frac{1000\ g}{1\ kg} \times \frac{1\ mol\ C_3H_8}{44.097\ g\ C_3H_8} \times \frac{3\ mol\ CO_2}{1\ mol\ C_3H_8} \times \frac{44.01\ g\ CO_2}{1\ mol\ CO_2} = \mathbf{299}4.08$$

$$= 2990\ g\ or\ 2.99 \times 10^3 g\ CO_2$$

e. How many moles of oxygen gas are required to form 5.25×10^{24} molecules of CO_2?

$$\mathbf{5.25} \times 10^{24}\ molecules\ CO_2 \times \frac{1\ mol\ CO_2}{6.02 \times 10^{23}\ molecules\ CO_2} \times \frac{5\ mol\ O_2}{3\ mol\ CO_2} = \mathbf{14.5}348$$

$$= 14.5\ mol\ O_2$$

f. If 15.0 g of C_3H_8 are burned in excess oxygen gas, how many molecules of water will be formed?

$$\mathbf{15.0}\ g\ C_3H_8 \times \frac{1\ mol\ C_3H_8}{44.097\ g\ C_3H_8} \times \frac{4\ mol\ H_2O}{1\ mol\ C_3H_8} \times \frac{6.02 \times 10^{23}\ molecules\ H_2O}{1\ mol\ H_2O}$$

$$= \mathbf{8.191} \times 10^{23} = 8.19 \times 10^{23} molecules\ H_2O$$

Page 1 of 3

Chemistry stoichiometry key is an essential concept in the field of chemistry that pertains to the calculation of reactants and products in chemical reactions. Understanding stoichiometry is crucial for chemists, as it allows them to predict the outcomes of reactions, determine the amounts of substances needed, and analyze the efficiency of reactions. This article will explore the foundational principles of stoichiometry, including mole concepts, balancing chemical equations, and applying stoichiometric calculations in various scenarios.

What is Stoichiometry?

Stoichiometry is derived from the Greek words "stoicheion," meaning element, and "metron," meaning measure. It refers to the quantitative relationships between the amounts of reactants and products in a chemical reaction. By employing stoichiometric principles, chemists can convert between different units of measurement, such as grams, moles, and liters, and make predictions about how much of a product will be formed based on the amounts of reactants used.

Key Concepts in Stoichiometry

To grasp the fundamentals of stoichiometry, several key concepts must be understood:

1. Mole Concept:
- A mole is defined as the amount of substance that contains the same number of entities (atoms, molecules, etc.) as there are in 12 grams of carbon-12. This number, known as Avogadro's number, is approximately 6.022×10^{23} entities per mole.
- Moles provide a bridge between the atomic scale and the macroscopic world, allowing chemists to count particles by weighing them.

2. Molar Mass:
- The molar mass of a substance is the mass of one mole of that substance, usually expressed in grams per mole (g/mol).
- Molar mass is calculated by summing the atomic masses of all atoms in a molecular formula.

3. Balanced Chemical Equations:
- A balanced chemical equation represents a chemical reaction with equal numbers of each type of atom on both sides of the equation. This reflects the law of conservation of mass, which states that matter cannot be created or destroyed in a chemical reaction.
- Balancing equations is necessary to perform stoichiometric calculations accurately.

Balancing Chemical Equations

To apply stoichiometry effectively, one must first balance the chemical equation representing the reaction. The following steps can be used to balance a chemical equation:

1. Write the Unbalanced Equation: Start by writing the chemical formulas of the reactants and products.

Example:
$$
\text{C}_3\text{H}_8 + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}
$$

2. Count Atoms of Each Element: Tally the number of atoms of each element in the reactants and products.

3. Balance One Element at a Time: Adjust coefficients in front of the chemical formulas to balance one element at a time. Start with the most complex molecule or the element that appears in the fewest compounds.

4. Repeat Until Balanced: Continue adjusting coefficients and recounting until all elements are balanced.

5. Check Your Work: Verify that the number of atoms of each element is the same on both sides of the equation.

Example of Balancing a Chemical Equation

Let's balance the combustion of propane:

Unbalanced equation:
$$
\text{C}_3\text{H}_8 + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}
$$

1. Count the atoms:
- Left: 3 C, 8 H, and 2 O (in O_2)
- Right: 1 C (in CO_2), 2 H (in H_2O), and 3 O (2 in CO_2 + 1 in H_2O)

2. Balance carbon:
$$
\text{C}_3\text{H}_8 + \text{O}_2 \rightarrow 3\text{CO}_2 + \text{H}_2\text{O}
$$

3. Balance hydrogen:
$$
\text{C}_3\text{H}_8 + \text{O}_2 \rightarrow 3\text{CO}_2 + 4\text{H}_2\text{O}
$$

4. Balance oxygen:
- Left: 2 O (in O_2)
- Right: 6 O (from $3CO_2$) + 4 O (from $4H_2O$) = 10 O
$$
\text{C}_3\text{H}_8 + 5 \text{O}_2 \rightarrow 3 \text{CO}_2 + 4 \text{H}_2\text{O}
$$

The final balanced equation is:
$$
\text{C}_3\text{H}_8 + 5 \text{O}_2 \rightarrow 3 \text{CO}_2 + 4 \text{H}_2\text{O}
$$

\]

Stoichiometric Calculations

Once a chemical equation is balanced, stoichiometric calculations can be performed to determine the relationships between moles of reactants and products. Here are the steps to follow:

1. Convert to Moles: If starting quantities are in grams, convert them to moles using the molar mass.

$$
\text{Moles} = \frac{\text{Mass (g)}}{\text{Molar Mass (g/mol)}}
$$

2. Use Mole Ratios: From the balanced equation, determine the mole ratios between the reactants and products. These ratios form the basis for calculations.

3. Calculate Amounts: Use the mole ratios to calculate the number of moles of the desired substance. Then, convert back to grams or other desired units if necessary.

Example of Stoichiometric Calculation

Using the balanced equation from the previous section, suppose we start with 44 grams of propane (C_3H_8):

1. Convert grams to moles:
$$
\text{Molar mass of } C_3H_8 = 3(12.01) + 8(1.008) = 44.1 \text{ g/mol}
$$
$$
\text{Moles of } C_3H_8 = \frac{44 \text{ g}}{44.1 \text{ g/mol}} \approx 1 \text{ mol}
$$

2. Use mole ratio: From the balanced equation, 1 mol of C_3H_8 produces 3 mol of CO_2.

3. Calculate moles of CO_2:
$$
\text{Moles of } CO_2 = 1 \text{ mol } C_3H_8 \times \frac{3 \text{ mol } CO_2}{1 \text{ mol } C_3H_8} = 3 \text{ mol } CO_2
$$

4. Convert moles of CO_2 to grams:

$$
\text{Molar mass of } CO_2 = 12.01 + 2(16.00) = 44.01 \text{ g/mol}
$$

$$
\text{Mass of } CO_2 = 3 \text{ mol} \times 44.01 \text{ g/mol} = 132.03 \text{ g}
$$

Thus, 44 grams of propane will produce approximately 132 grams of carbon dioxide.

Applications of Stoichiometry

Stoichiometry is not confined to the laboratory; it has practical applications in various fields, including:

- Pharmaceuticals: Calculating dosages and the quantities of reactants needed for drug synthesis.
- Environmental Science: Assessing the impact of chemical reactions in pollution control and remediation.
- Food Industry: Determining the ingredient proportions in recipes and formulations.
- Industrial Chemistry: Optimizing production processes by minimizing waste and maximizing yield.

Conclusion

In summary, the chemistry stoichiometry key is vital for understanding and predicting the outcomes of chemical reactions. By mastering the concepts of moles, molar mass, and balanced equations, chemists can perform accurate stoichiometric calculations, which are essential in various scientific and industrial applications. Whether in the laboratory or in real-world scenarios, stoichiometry remains a foundational skill for anyone working in the field of chemistry.

Frequently Asked Questions

What is stoichiometry in chemistry?

Stoichiometry is the branch of chemistry that involves the calculation of reactants and products in chemical reactions using balanced equations to determine the proportions of elements and compounds.

How do you balance a chemical equation for stoichiometry?

To balance a chemical equation, adjust the coefficients of the reactants and products to ensure that the number of atoms of each element is the same on both sides of the equation.

What is the significance of the mole concept in stoichiometry?

The mole concept is crucial in stoichiometry as it provides a bridge between the atomic scale and macroscopic scale, allowing chemists to count particles (atoms, molecules, etc.) by weighing them in grams.

What is a limiting reactant in stoichiometry?

The limiting reactant is the substance that is completely consumed in a chemical reaction, determining the maximum amount of product that can be formed based on the stoichiometric ratios.

How do you calculate the theoretical yield in a stoichiometric reaction?

The theoretical yield can be calculated by determining the moles of the limiting reactant and using the stoichiometric coefficients from the balanced equation to find the maximum amount of product that can be formed.

What role do coefficients play in stoichiometric calculations?

Coefficients in a balanced chemical equation indicate the relative number of moles of each substance involved in the reaction, which is essential for calculating the amounts of reactants and products.

Can stoichiometry be applied to solutions in chemistry?

Yes, stoichiometry can be applied to solutions by using molarity (moles per liter) to relate the volume of solutions to the moles of solute, allowing for calculations involving reactions in solution.

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