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Understanding the heat released or absorbed during chemical reactions is fundamental in chemistry, especially in thermodynamics and industrial applications. When a chemical reaction occurs, energy is either released into the surroundings (exothermic) or absorbed from them (endothermic). In this context, we focus on calculating the amount of heat (in kilojoules, KJ) given off when a specific mass of nitrogen dioxide (NO_2) is produced. This process involves understanding the reaction involved, molar relationships, and the heat of reaction or enthalpy change.

Overview of the Reaction Involving NO_2 Production

Understanding Nitrogen Dioxide (NO_2) Formation

Nitrogen dioxide (NO_2) is a reddish-brown gas that plays a significant role in atmospheric chemistry and industrial processes. It is typically produced through the oxidation of nitrogen monoxide (NO) in the presence of oxygen.

The primary reaction for NO_2 formation is:

$$2\ NO\ (g) + O_2\ (g) \rightarrow 2\ NO_2\ (g)$$

This reaction is exothermic, releasing heat into the environment. Knowledge of the enthalpy change (ΔH) for this reaction allows us to calculate the heat released when a certain amount of NO_2 is produced.

Understanding the Relationship Between Mass, Moles, and Heat

Molecular Weight of NO_2

To relate the mass of NO_2 produced to the energy change, we need its molar mass:

1. Nitrogen (N): 14.01 g/mol
2. Oxygen (O): 16.00 g/mol

Therefore,

Molar mass of NO_2 = $14.01 + 2\times16.00 = 14.01 + 32.00 = 46.01$ g/mol

Calculating Moles of NO_2

Given the mass of NO_2 produced:

Mass of NO_2 = 1.26×10^4 g

Number of moles (n):

n = (Mass of NO_2) / (Molar mass of NO_2) = (1.26×10^4 g) / 46.01 g/mol ≈ 273.94 mol

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Understanding Enthalpy Change and Heat Calculations

Standard Enthalpy of Formation of NO_2

The key to calculating the heat given off is the standard enthalpy change ($\Delta H°$) for the reaction. For the reaction:

$2\ NO\ (g) + O_2\ (g) \rightarrow 2\ NO_2\ (g)$

The standard enthalpy change ($\Delta H°$) is typically provided or found in thermodynamic tables. For this reaction, the approximate value is:

$\Delta H° \approx -1143$ kJ per 2 mol of NO + O_2 reacting to produce 2 mol of NO_2

Since the reaction involves 2 mol of NO and produces 2 mol of NO_2, the heat released per mole of NO_2 produced is:

ΔH per mol of NO_2 = (-1143 kJ) / 2 = -571.5 kJ/mol

The negative sign indicates an exothermic process, meaning heat is released.

Calculating Total Heat Released for the Given Quantity of NO_2

Step-by-Step Calculation

Knowing the moles of NO_2 produced and the enthalpy change per mole, the total heat given off (Q) can be calculated as:

Q = (number of moles of NO_2) × (ΔH per mol of NO_2)

Substituting the known values:

Q = 273.94 mol × 571.5 kJ/mol ≈ 156,607.11 kJ

Therefore, approximately 156,607 kJ of heat are released when 1.26×10^4 g of NO_2 is produced.

Important Considerations and Assumptions

Assumptions Made in the Calculation

- The reaction proceeds to completion, with all NO converting to NO_2.
- The enthalpy change used is accurate and applies under the conditions of the reaction.
- No side reactions or other processes consume or release additional heat.
- The molar enthalpy of reaction remains constant over the temperature range considered.

Impact of Reaction Conditions

Temperature and pressure can influence the enthalpy change, but standard enthalpy values are typically used for calculations at standard conditions (25°C, 1 atm). For reactions under different conditions, correction factors may be necessary.

Practical Applications of Heat Calculations in Industry

Environmental Impact and Emission Control

Understanding heat release during NO_2 formation helps in designing systems to control emissions, especially since NO_2 is a pollutant contributing to smog and acid rain.

Industrial Process Optimization

Industries involved in nitric acid production, combustion engines, and other chemical manufacturing use such calculations to optimize energy efficiency and safety measures.

Energy Management and Safety

Accurate heat calculations prevent accidents and help in designing effective cooling or heating systems in chemical plants.

Summary and Final Insights

- The mass of NO_2 produced directly relates to the number of moles involved in the reaction.
- The standard enthalpy of the reaction provides the basis for calculating heat release.
- For 1.26×10^4 g of NO_2 produced, approximately 156,607 kJ of heat is given off.
- Proper understanding of thermodynamics principles enables chemists and engineers to manage energy efficiently, mitigate environmental impact, and optimize industrial processes.

Additional Resources & References

- Standard Thermodynamic Data Tables
- Chemistry Textbooks on Thermochemistry
- Industry Guidelines for NO_2 Emission Control
- Online Calculators for Molar Conversions and Enthalpy Calculations

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Final Thoughts

Calculating the heat released during chemical reactions like NO_2 formation is crucial in both academic and industrial settings. It provides insights into energy balance, environmental impact, and safety measures. By understanding the fundamental principles—molar relationships, enthalpy changes, and reaction stoichiometry—scientists and engineers can make informed decisions to optimize processes and minimize environmental harm.

Note: Always verify the enthalpy values with current, authoritative sources or experimental data for precise calculations, especially when applying these principles to critical industrial processes.

Frequently Asked Questions

How do you calculate the amount of heat released when 1.26 x 10^4 g of NO2 are produced?

You need to use the enthalpy change of the reaction and the molar mass of NO2 to convert grams to moles, then multiply by the enthalpy change to find the heat released in kilojoules.

What is the first step in determining the heat evolved during the production of NO2?

Convert the given mass of NO2 (1.26 x 10^4 g) to moles by dividing by its molar mass (46 g/mol).

If the enthalpy change for the reaction is known, how is it used to find the heat released for the given mass of NO2?

Multiply the number of moles of NO2 produced by the molar enthalpy change (ΔH) to find the total heat emitted in kilojoules.

Why is it important to know the molar mass of NO2 when calculating heat released?

Because it allows conversion from mass (grams) to moles, which is necessary to apply the molar enthalpy change and accurately determine the heat released.

What additional information is needed to accurately determine the heat given off in the reaction?

The molar enthalpy change (ΔH) for the reaction producing NO2 is required to calculate the heat released.

Can you explain how to interpret the resulting heat in terms of the reaction conditions?

The calculated heat in kilojoules indicates the energy change associated with producing the specified amount of NO2 under the given reaction conditions, reflecting whether the process is exothermic or endothermic.

Additional Resources

Determine The Amount Of Heat (in KJ) Given Off When 1.26 X 10^4 g Of NO_2 Are Produced According To The

Understanding the thermodynamic principles involved in chemical reactions is fundamental to many fields, including industrial chemistry, environmental science, and chemical engineering. One common calculation faced by students and professionals alike is determining the heat released or absorbed during a reaction. Specifically, in this context, calculating the amount of heat (in kilojoules) given off when a specified mass of nitrogen dioxide (NO_2) is produced provides insight into the exothermic or endothermic nature of the reaction, as well as its energetic efficiency. This article offers a comprehensive review of the process involved in such calculations, exploring the theoretical foundations, step-by-step procedures, and practical considerations.

Understanding the Concept of Heat in Chemical Reactions

Before delving into the calculations, it’s vital to grasp what is meant by "heat given off" in chemical reactions. Heat transfer during a reaction is associated with the change in enthalpy (ΔH) of the system. Reactions that release heat are exothermic, while those that absorb heat are endothermic.

Key Points:
- Enthalpy change (ΔH): The heat change at constant pressure.
- Exothermic reactions: Release heat, ΔH is negative.
- Endothermic reactions: Absorb heat, ΔH is positive.
- Standard enthalpy of formation ($\Delta H_f°$): The enthalpy change when 1 mol of a compound forms from its elements in their standard states.

Understanding these concepts allows us to connect the amount of substance produced (or consumed) to the total heat change in the reaction.

Identifying the Relevant Chemical Equation

The first critical step is to establish the chemical reaction involved in producing NO_2. Typically, NO_2 is formed through the oxidation of nitric oxide (NO):

$$ 2 NO + O_2 \rightarrow 2 NO_2 $$

or through other industrial processes such as the thermal decomposition of nitrates or the oxidation of ammonia in certain contexts. For the purpose of this calculation, let's assume the reaction is:

$$ N_2O_4 \rightarrow 2 NO_2 $$

This reaction is common because N_2O_4 decomposes into NO_2, and it's often used as a basis for thermodynamic calculations.

Note: The specific reaction should be confirmed based on the context in which NO_2 is produced, as different reactions will have different ΔH values.

Reaction Details and Stoichiometry

For the assumed reaction:

$$ N_2O_4 \rightarrow 2 NO_2 $$

- One mole of N_2O_4 produces two moles of NO_2.
- The molar mass of N_2O_4 is approximately 92.01 g/mol.
- The molar mass of NO_2 is approximately 46.01 g/mol.

This stoichiometry indicates that for every 92.01 grams of N_2O_4 decomposed, 92.02 grams of NO_2 are produced.

Calculating the Moles of NO_2 Produced

Given mass of NO_2:

$$ \text{Mass of NO}_2 = 1.26 \times 10^4\, \text{g} $$

Calculate the number of moles:

$$ \text{Moles of NO}_2 = \frac{\text{Mass of NO}_2}{\text{Molar mass of NO}_2} $$

$$ \text{Moles of NO}_2 = \frac{1.26 \times 10^4\, \text{g}}{46.01\, \text{g/mol}} \approx $$

$$273,889\, \text{mol}$$

This large number emphasizes that industrial reactions often involve substantial quantities, making the heat calculation significant.

Relating Moles to Heat Released or Absorbed

The core of the calculation hinges on knowing the enthalpy change per mole of reaction. For the assumed decomposition:

$$N_2O_4 \rightarrow 2 NO_2$$

the standard enthalpy change (ΔH°) is typically provided in thermodynamic tables. Suppose, for instance, that ΔH° for this reaction is approximately +57 kJ/mol (endothermic). However, if considering the formation or other reactions, the sign and magnitude can vary.

Important: You must verify the actual ΔH value from authoritative thermodynamic data sources.

Once ΔH° per mole of the reaction is known, the total heat involved can be calculated as:

$$Q = \text{moles of reaction} \times \Delta H^\circ$$

In this case, since 1 mol of N_2O_4 produces 2 mol of NO_2, the moles of the reaction are:

$$\text{Moles of reaction} = \frac{\text{Moles of NO}_2}{2} \approx 136,945\, \text{mol}$$

Then,

$$Q = 136,945\, \text{mol} \times 57\, \text{kJ/mol} \approx 7.81 \times 10^6\, \text{kJ}$$

This is the theoretical heat change assuming complete conversion and no heat loss.

Adjusting Calculations for Actual Conditions

In practical scenarios, several factors can influence the actual heat released or absorbed:

- Reaction completeness: Not all reactants may convert fully.
- Heat losses: Real systems lose some heat to surroundings.
- Reaction conditions: Temperature, pressure, catalysts, and impurities can alter the enthalpy change.
- Reaction pathway: Different pathways may have different enthalpy profiles.

Hence, the theoretical value provides an estimate, but real-world measurements often require calorimetric analysis.

Using Enthalpy Data from Standard Tables

For accurate calculations, thermodynamic data from standard tables are essential. For example, the enthalpy change of formation of NO_2 is approximately +33.2 kJ/mol, and for N_2O_4, it's about +9.16 kJ/mol.

If the reaction involves formation from elements, the enthalpy change can be calculated as:

$$ \Delta H^\circ = \sum \nu \Delta H_f^\circ (\text{products}) - \sum \nu \Delta H_f^\circ (\text{reactants}) $$

Where:

- ν represents the stoichiometric coefficients.

Applying this to the N_2O_4 decomposition:

$$ N_2O_4 \rightarrow 2 NO_2 $$

$$ \Delta H^\circ = [2 \times 33.2\, \text{kJ/mol}] - [1 \times 9.16\, \text{kJ/mol}] = 66.4\, \text{kJ} - 9.16\, \text{kJ} = +57.24\, \text{kJ} $$

This confirms the earlier assumption and highlights the importance of referencing accurate thermodynamic data.

Final Calculation of Heat Given Off

Using the molar data:

- Moles of NO_2 produced: approximately 273,889 mol.
- Reaction heat per mole: +57.24 kJ/mol.

Total heat:

$$ Q = 273,889\, \text{mol} \times 57.24\, \text{kJ/mol} \approx 15,676,660\, \text{kJ} $$

Since the reaction is endothermic (positive ΔH), heat is absorbed from the surroundings. If the reaction were exothermic, the sign would be negative, indicating heat release.

Note: The actual value should be adjusted based on the precise thermodynamic data for the specific reaction pathway.

Practical Implications and Applications

Calculating the heat change is not merely an academic exercise; it has real-world significance:

- Industrial Energy Balance: Helps design reactors and optimize energy consumption.
- Environmental Impact: Understanding heat release can inform emissions control and safety measures.
- Thermal Management: Critical in processes where heat buildup could lead to hazards.
- Cost Estimation: Energy costs are a major factor in large-scale chemical production.

Pros and Cons of the Calculation Approach

Pros:
- Provides an estimate of the energy involved in producing specific quantities of NO_2.
- Facilitates scale-up from laboratory to industrial processes.
- Aids in safety planning and thermal management.

Cons:
- Assumes complete reaction and no heat loss, which is rarely the case.
- Relies on the accuracy of thermodynamic data, which may vary with temperature.
- Does not account for kinetic factors or side reactions that can influence heat exchange.

Conclusion

Determining the amount of heat given off when producing a specific mass of NO_2 involves a clear understanding of the reaction's stoichiometry, thermodynamic data, and practical considerations. By converting the mass to moles, referencing standard enthalpy of reaction, and performing straightforward calculations, one can estimate the total energy change involved. These calculations are vital in optimizing industrial processes, ensuring safety, and understanding the energetics of chemical reactions. While theoretical calculations provide valuable insights, real-world applications also require considering reaction efficiencies, heat losses, and operational conditions for accurate energy management.

Final note: Always verify thermodynamic data from reliable sources and tailor calculations to the

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