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STUDY OF ENVIRONMENTALLY SAFE AND ENERGY-EFFICIENT METHODS FOR THE PRODUCTION OF CHEMICAL SUBSTANCES IN THE CONTEXT OF THE CONCEPT OF SUSTAINABLE DEVELOPMENT

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ABSTRACT

The article examines modern approaches to the development of environmentally safe and energy-efficient methods for the production of chemical substances. Key principles of sustainable development are analyzed, including the application of green technologies, next-generation catalysts, renewable energy sources, and closed production cycles. Promising directions for optimizing chemical-technological processes aimed at minimizing environmental impact and improving resource efficiency are identified.

KEYWORDS

Sustainable development, green chemistry, energy efficiency, environmental safety, catalysis, chemical production.

Introduction

The growth of global chemical production is accompanied by increasing pressure on the environment and higher energy consumption. In this regard, the problem of creating environmentally safe and energy-efficient technologies has become central in the chemical industry. The concept of sustainable development implies harmonizing economic growth, social stability, and environmental safety. In the chemical industry this is reflected in the transition to processes that minimize resource consumption, reduce waste generation, and introduce harmless or low-toxicity reagents.

The concept of sustainable development includes three key elements: environmental safety, economic efficiency, and social responsibility. In chemical production these criteria are implemented through the principles of green chemistry, including:

- prevention of waste generation;
- use of safe solvents;
- use of renewable raw materials;
- energy-saving processes;
- increasing the atom efficiency of reactions.

These principles have become the methodological basis for developing innovative technological schemes aimed at reducing negative impacts on ecosystems.

Energy-Efficient Methods for Chemical Production

1. Use of Next-Generation Catalysts

Catalysts based on nanomaterials, metal-organic frameworks (MOF), and biocatalysts make it possible to conduct reactions at lower temperatures and pressures, significantly reducing energy consumption. Catalytic processes are characterized by high selectivity, which increases the yield of target products.

2. Application of Renewable Energy Sources

Heliochemical, photochemical, and electrolytic synthesis methods use solar energy, electricity, and other renewable resources. For example, photocatalytic hydrogen production processes help reduce the use of fossil fuels.

3. Process Intensification

Microreactors, ultrasonic activation, and plasma technologies accelerate chemical reactions without increasing energy consumption. These methods increase safety, shorten production cycles, and reduce emissions.

Environmentally Safe Methods for Obtaining Chemical Substances

1. Biotechnological Processes

Enzymatic and microbiological synthesis methods make it possible to produce chemical substances under mild conditions without the use of toxic reagents. They represent a key direction in the development of white biotechnology.

2. Replacement of Toxic Solvents with Green Alternatives

Instead of traditional organic solvents, ionic liquids, supercritical CO2, and water in supercritical conditions are used. Such media are safe and provide high dissolving capacity.

3. Creation of Closed Production Cycles (Circular Chemistry)

The use of closed cooling systems, heat recovery, and recycling of waste ensures a reduction in environmental impact. Closed cycles reduce the need for raw materials and minimize emissions.

Digitalization and Modeling as Tools for Sustainable Development

Modern instrumental methods such as machine learning, 3D modeling, and computational programs (CFD, Aspen Plus) allow prediction of optimal process parameters, minimization of energy consumption, and reduction of environmental risks. Digital twins of chemical plants are an effective tool for increasing production sustainability.

Application of Green Technologies in Global and National Practice

In developed countries, low-carbon technologies such as catalytic oxidation, combined biochemical processes, and the production of biodegradable polymers are actively implemented. In Uzbekistan's industry, measures are gradually being implemented to modernize chemical complexes, including the transition to energy-efficient equipment, new types of purification facilities, and automated emission monitoring systems.

The study of environmentally safe and energy-efficient methods for the production of chemical substances is one of the most important directions for the development of the modern chemical industry. The application of green chemistry principles, the introduction of next-generation catalysts, digitalization of processes, and the use of renewable energy sources create the foundation for sustainable and environmentally safe development of the industry. Promising areas include expanding

research in biocatalysis, creating closed production cycles, and integrating digital technologies into chemical process management.

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