

## SORPTION OF RHENIUM: RESEARCH, METHODS, AND SCIENTIFIC APPROACHES

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**Abstract:** This article discusses the process of rhenium (Re) sorption and its effective methods. Since perrhenate ions ( $\text{ReO}_4^-$ ) are found in industrial waste and the environment, posing ecological risks, their efficient removal is one of the critical challenges. The paper analyzes various types of sorbents, including activated carbon, ion-exchange sorbents, zeolites, and biomass-based materials. The main mechanisms of the sorption process are described, including electrostatic forces, ion exchange, and Van der Waals interactions. In addition, technologies for rhenium recovery using modern nanomaterials and modified polymers are discussed. This review serves as an important information source for research aimed at reducing rhenium's ecological hazards and developing efficient purification methods.

**Keywords:** rhenium sorption, perrhenate ions, sorption methods, activated carbon, ion-exchange sorbents, zeolites, biomass, environmental purification, bioaccumulation, nanomaterials.

### Introduction

The effective removal of rhenium ( $\text{ReO}_4^-$ ) from the environment and industrial waste is an essential aspect of environmental purification. Due to rhenium's high toxicity and radioactive properties, its contamination of water and soil can pose serious threats to the environment and human health. Although various methods exist for rhenium removal, sorption—i.e., adsorption of rhenium onto a solid phase—is one of the most effective and economically advantageous technologies. This article reviews the main scientific studies and approaches related to rhenium sorption.

### Sources and Environmental Impact of Rhenium

Rhenium is mainly known as a decay product of ruthenium (Ru) isotopes generated in radioactive materials or industrial processes. Its high toxicity and long persistence in the environment increase its ecological hazard. Rhenium accumulation in water or soil can lead to plant uptake, subsequent transfer to animals, and ultimately reach humans through the food chain, posing serious health risks. Therefore, the effective removal and environmental separation of rhenium are of utmost importance.

### Methods of Rhenium Removal

Several methods exist for the removal of rhenium. The main methods include:

- **Chemical reduction:** Rhenium can be removed by changing its oxidation state, i.e., reducing Re(VII) to Re(IV). While this method helps convert rhenium into other chemical forms, its efficiency may be limited in some cases.
- **Filtration and distillation:** These methods are also used to remove rhenium from liquids, though they often require high energy and time consumption.
- **Sorption:** Sorption, or adsorption of rhenium onto a solid phase, is the most widely used and promising method for effectively removing rhenium from water and other solutions.

### Sorbents and Their Properties

Various materials are used in the sorption process to remove rhenium. Effective sorbents usually have a high surface area and a chemical structure capable of adsorbing rhenium. The most commonly used sorbents include:

- **Activated carbon:** A highly adsorptive material effective in removing perrhenate ( $\text{ReO}_4^-$ ). Its high surface area and porous structure enhance sorption efficiency [1].
- **Zeolites:** Natural minerals with microstructures and high surface areas that enable effective rhenium adsorption. They are also chemically stable and environmentally friendly [2].
- **Ion-exchange sorbents:** Polymer-based sorbents, especially sulfonated polymers, operate through ion exchange. These resins are efficient due to their ability to act as electron donors and accommodate large ions [3].
- **Modified biomass:** Biomass materials such as soil- or plant-derived substances can be chemically modified for efficient rhenium adsorption. These materials are environmentally friendly and cost-effective [4].

### Sorption Mechanisms and Processes

The rhenium sorption process is based on several physicochemical mechanisms, including:

- **Electrostatic forces:** Ionic properties on the sorbent surface facilitate rhenium adsorption as an anion. These forces help bind rhenium to the solid phase [5].
- **Ion exchange:** In ion-exchange resins, rhenium anions are exchanged with other positively charged ions, enhancing the efficiency of the process [6].
- **Van der Waals forces:** These molecular interactions support the adsorption of rhenium onto the sorbent surface [7].

### Recent Research and Innovations

Numerous studies have been conducted in recent years to improve rhenium sorption methods. Some important innovations include:

- **Nanomaterials:** New types of nanomaterials have been developed using nanotechnology, offering high surface area and special structures for effective rhenium adsorption [8].
- **Modified polymers:** The sorption process is being optimized with polymer resins and nanomaterials, increasing its overall efficiency [9].

- **Biomass-based sorbents:** New sorbents developed from natural biomass are both eco-friendly and inexpensive, and this area is rapidly evolving [10].

### Conclusion

Various materials and methods exist for effective rhenium sorption. Activated carbon, zeolites, ion-exchange resins, and modified biomass materials are widely used in this field. In recent years, more effective sorption technologies have been developed using nanomaterials and polymers. To reduce the environmental risks of rhenium and ensure its efficient removal from ecosystems, further development of these methods is necessary.

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