CHARACTERIZATION AND LOW-TEMPERATURE STABILITY OF ION-EXCHANGE RESINS

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Abstract. This study evaluates the physicochemical and technological properties of ion-exchange resins used in ion-exchange processes. Eight resins, including BO-020, AMP, Purolite A-606, BD-706, Tulsion A-3663, Amberlite IRA-120, Resinacs, and Dowex-1, were investigated. Granulometric composition, mechanical strength, specific surface area, density, porous structure, selectivity, regeneration properties, and resistance to low temperatures were analyzed. The results showed significant differences among the investigated resins. BO-020 demonstrated the highest quality degree (88%) and the largest specific surface area (65.00 m²/g), while AMP showed 85% and 54.00 m²/g, respectively. Low-temperature tests indicated that freezing affects mechanical strength and particle size, particularly in larger fractions. Smaller particles showed greater stability during freezing. The obtained results demonstrate the importance of comprehensive evaluation of physicochemical, mechanical, structural, and temperature-resistant properties when selecting ion-exchange resins for practical applications.

Keywords: ion-exchange resins; physicochemical properties; granulometric composition; mechanical strength; specific surface area; low-temperature resistance.

INTRODUCTION

Ion-exchange resins are widely used as functional polymeric materials in hydrometallurgical processes because of their ability to selectively remove and concentrate dissolved ionic components from aqueous solutions. Their performance is strongly influenced by the structure of the polymer matrix, the nature of functional groups, degree of cross-linking, hydration behavior, and accessibility of exchange sites. Therefore, understanding the relationship between the structural characteristics of ion-exchange materials and their technological performance is essential for improving separation processes.

The efficiency of an ion-exchange resin is closely related to its porous structure and swelling behavior. Hydration of functional groups causes expansion of the polymer network and facilitates the diffusion of ions through the resin phase. At the same time, the degree of cross-linking affects pore dimensions, mechanical stability, water uptake, and ion mobility. Consequently, variations in the polymer structure can produce significant differences in exchange capacity, selectivity, and mass-transfer characteristics.

Mechanical and physical stability are also important factors during industrial operation. Ion-exchange resin granules are subjected to hydraulic flow, pressure changes, repeated regeneration, swelling and contraction, and contact with technological solutions. These factors may gradually alter the integrity of the granules and affect the hydraulic resistance and efficiency of the ion-exchange bed. Particle size and distribution are particularly important because they influence solution flow, contact area, diffusion distance, and the stability of the packed layer.

Another important characteristic is the behavior of ion-exchange materials under changing environmental conditions. Water contained within the polymer pores can significantly affect the structural state of the resin during cooling. At low temperatures, phase changes of water and associated volume changes may generate internal stresses in the polymer framework. Such effects can lead to deformation or destruction of resin granules and consequently influence their further technological performance.

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Therefore, the present study focuses on the comprehensive characterization of ion-exchange resins through their granulometric composition, mechanical strength, swelling behavior, density, porous structure, specific surface area, ion-exchange capacity, selectivity, and stability under temperature effects. The objective is to establish the relationship between these characteristics and the functional performance of ion-exchange materials and to identify the structural factors that determine their suitability for practical ion-exchange and hydrometallurgical applications.

MATERIALS AND METHODS

Eight ion-exchange resins, including BO-020, AMP, Purolite A-606, BD-706, Tulsion A-3663, Amberlite IRA-120, Resinacs, and Dowex-1, were investigated. The main parameters evaluated were granulometric composition, mechanical strength, specific surface area, density, porous structure, ion-exchange capacity, selectivity, regeneration, and low-temperature resistance. Granulometric composition was determined using wet and dry sieve methods, while mechanical strength was evaluated after controlled mechanical treatment of swollen resin samples.

For low-temperature testing, resin samples were frozen at −25 °C for 24 h and then thawed at +20 °C for 24 h. Changes in mechanical strength and average particle diameter were determined before and after freezing. Particle fractions of <0.3 mm, 0.3–0.8 mm, and >0.8 mm were considered to evaluate the relationship between particle size and resistance to cryodestruction. The obtained results were compared using the main physicochemical and technological parameters to assess the stability and practical suitability of the investigated ion-exchange resins.

RESULTS

The results demonstrated significant differences in the physicochemical and technological characteristics of the investigated ion-exchange resins. The granulometric analysis showed that BO-020 had the highest proportion of the working fraction, while Purolite A-606, Dowex-1, Amberlite IRA-120, and Tulsion A-3663 were characterized by finer particle sizes. The mechanical strength of the resins followed the order AMP > BO-020 > Purolite A-606 > Tulsion > BD-706 > Amberlite IRA-120 > Dowex-1.

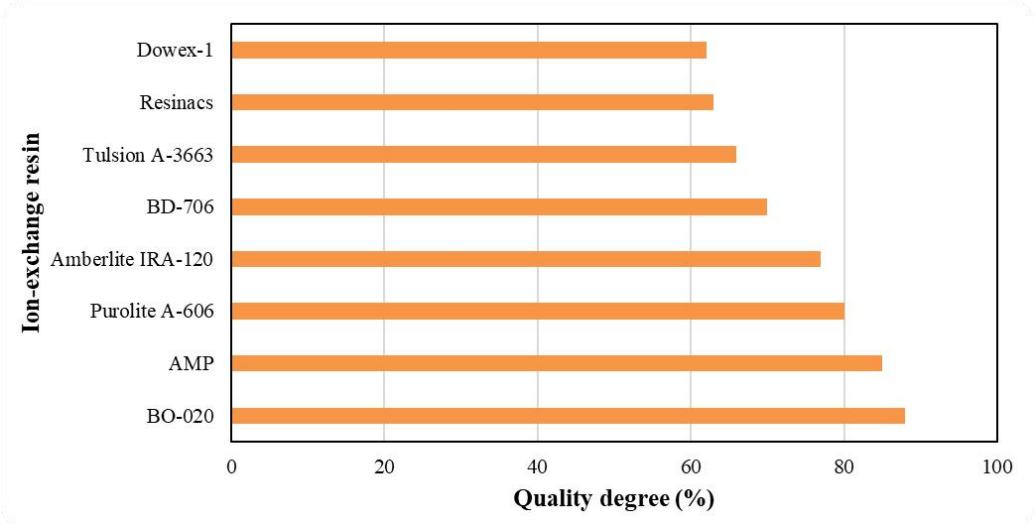


Figure 1. Quality degree of the investigated ion-exchange resins

The porous characteristics also varied considerably among the investigated materials. BO-020 showed the highest specific surface area (65.00 m^2/g), followed by AMP (54.00 m^2/g) and BD-706 (51.69 m^2/g). The other resins had lower specific surface areas, indicating differences in their internal structure and available sorption surface.

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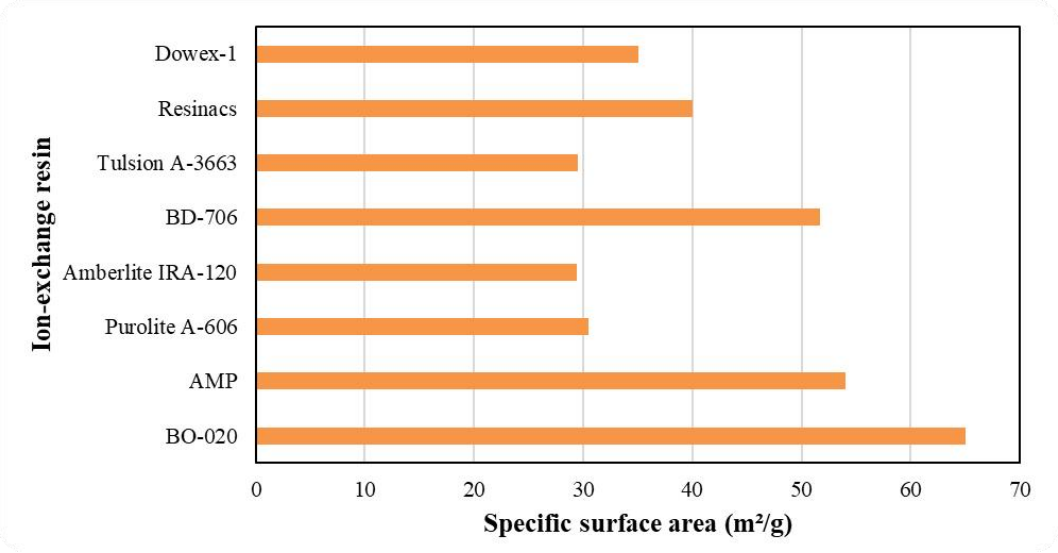


Figure 2. Comparison of the specific surface area of the investigated ion-exchange resins

Low-temperature testing showed that freezing affected both the mechanical strength and particle size of the resins. Particles smaller than 0.3 mm demonstrated comparatively high stability, whereas the 0.3–0.8 mm fraction showed cracking and breakage. Particles larger than 0.8 mm experienced more pronounced destruction. The integrated assessment based on granulometric composition, mechanical strength, specific surface area, density, selectivity, and regeneration properties showed the following quality sequence: BO-020 > AMP > Purolite A-606 > Amberlite IRA-120 > BD-706 > Tulsion > Resinacs > Dowex-1.

CONCLUSION

The study demonstrated that the investigated ion-exchange resins have different physicochemical and technological characteristics that affect their suitability for ion-exchange processes. The comparative assessment showed that BO-020 had the highest quality degree (88%) and the largest specific surface area (65.00 m²/g), followed by AMP with 85% and 54.00 m²/g, respectively. The results confirm that resin quality should be assessed using a combination of granulometric composition, mechanical strength, porous structure, specific surface area, density, selectivity, and regeneration characteristics.

Low-temperature experiments showed that freezing can cause changes in the mechanical strength and particle size of ion-exchange resins. Smaller particles demonstrated greater resistance to low-temperature effects, whereas larger fractions were more susceptible to cracking and destruction. BO-020 showed comparatively stable characteristics after freezing, while A-606 and AMP exhibited more pronounced changes. These results emphasize the importance of considering both physicochemical properties and low-temperature stability when selecting ion-exchange resins for practical applications.

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