INTRODUCTION

The separation or isolation of components from solutions with complex composition is performed using various chemical and electrochemical methods, by separation, precipitation, extraction, sorption concentration, and selective reduction. The isolation of heavy metal ions from a solution of nickel chloride occurs most effectively on Purolite D24002 macroporous chelate forming ion exchanger, KU-23-15/100 sulfo cation exchanger, and KU-2-8 gel sulfo cation exchanger. Nickel enters sulfo cation exchangers in the form of counterions, and is adsorbed on Purolite D24002 largely because of complex formation. The subsequent precipitation of nickel in the solid state in matrix pores liberates ionogenic centers, which allows repeated sorption cycles to be performed. After three chemical precipitation cycles under static conditions, the amount of nickel is higher by 170–250% than the ion exchange capacity of the sorbents. The electrolyte of chemical nickel plating contains nickel predominantly in the form of negatively charged and neutral complexes with glycine, which cannot form bonds with the matrices under study. It is therefore reasonable to perform sorption at decreased solution pH values.

EXPERIMENTAL

We used a series of ion exchangers of various natures, including Purolite A109 low-basicity amino-containing anion exchanger, Purolite D24002 chelate-forming iminodiacetate polyanionoplyte, KU-23 15/100 macroporous strongly acid sulfo cation exchanger, and KU-2-8 gel strongly acid sulfo cation exchanger. Their main characteristics are listed in
The solutions studied were a 0.125 M solution of nickel chloride and an electrolyte of chemical nickel plating bath (pH 6) with the composition 0.125 M nickel chloride, 0.2 M aminoacetic acid NH₂CH₂COOH (HGly), and 0.12 M sodium acetate CH₃COONa.

Before the precipitation of nickel ions, ion exchangers and carbons (bulk volume 3 cm³) were preliminarily saturated under static conditions by a solution containing Ni²⁺ ions (50 cm³) for 3 days until ion exchange equilibrium was established. The accumulation of nickel ions in a matrix from a solution of nickel chloride was performed in the form of poorly soluble Ni(OH)₂, hydroxide. For this purpose, ion exchangers in the Ni²⁺ form washed with distilled water were treated with a 2.5% solution of sodium hydroxide (30 cm³). The ion exchange saturation—chemical precipitation cycle was performed three times. To decrease the concentration of nickel ions transferred into solution because of partial solution of nickel hydroxide, Ni²⁺ counterions were also precipitated in the form of nickel carbonate, or reduction to metal was performed using an alkaline solution of sodium dithionite (6% Na₂S₂O₄ in 2.5% NaOH, 50 cm³). By such means, Ni²⁺ counterions were transformed into a coordination inactive form.

The residual concentration of Ni²⁺ ions in solution was determined by complexometric titration using Trilon B and murexide as an indicator [14]. The difference between the initial solution concentration and solution concentration after contact with sorbents was used to find the equilibrium degrees of sorption of nickel ions by various ion exchangers,

\[ \alpha = \frac{(c_0 - c)V}{\varepsilon_H \overline{V}} \]  

where \( c_0 \) is the initial concentration of nickel ions in solution, mol/l; \( c \) is the concentration of nickel ions in solution after contact with the sorbent, mol/l; \( \varepsilon_H \) is the ion exchange capacity of the sorbent with respect to H⁺, mmol/cm³; \( V \) is the volume of saturation solution, cm³; and \( \overline{V} \) is the volume of the swollen ion exchanger, cm³.

RESULTS AND DISCUSSION

First, we studied the sorption ability of all the ion exchange matrices (anion and cation exchangers and ampholyte) and carbons with respect to nickel ions under static conditions. For this purpose, we performed sequential cycles of saturation of matrices with nickel ions from a 0.125 M solution of nickel chloride and their precipitation in the form of nickel hydroxide.

When strongly acid KU-23-15/100 and KU-2-8 sulfo cation exchangers are saturated with nickel ions, ion exchange

\[ 2\text{R–SO}_3\text{H}^+ + \text{Ni}^{2+} \rightleftharpoons (\text{R–SO}_3\text{Ni})^+ + 2\text{H}^+ \]  

occurs. In Purolite A109 amine-containing anion exchanger, nickel ions form coordination bonds with matrix amine groups to form complexes with the participation of the lone electron pair of nitrogen [15].

\[ 2\text{R–NH}_2 + \text{Ni}^{2+} \rightleftharpoons [(\text{R–NH}_2) \rightarrow \text{Ni}^{2+}] \]  

Purolite D24002 iminodiacetate ampholyte participates in complex formation with nickel at the expense of not only the electron pair of the tertiary nitrogen atom but also of the electron pair of carboxyl oxygen, because carboxyl groups are weakly dissociated [15].

As a result,

\[ \text{R–N(CH}_2\text{COOH)}_2 + \text{Ni}^{2+} \rightleftharpoons [\text{R–N(CH}_2\text{COOH)}_2 \rightarrow \text{Ni}^{2+}] \]  

chelate complexes are formed. Carbons sorb nickel ions because of the presence of a small amount of sulfo, carboxyl, and phenol groups [16].

After the ion exchange saturation of matrices and washing off electrolyte absorbed in a nonexchange process, nickel ions were precipitated in the form of nickel hydroxide as [17]

\[ (\text{R–SO}_3\text{Ni})^+ + 2\text{NaOH} \rightarrow [\text{R–SO}_3\text{Na}^+]_\text{2} \cdot \text{Ni(OH)}_2 \]