Due to the combination of active functional atomic groups (amine and oxyethyl), \(N\)-(2-hydroxyethyl)alkyl amines (HEA) are objects of interest for investigation. Some of them are known as nonionogenic surfactants [1], and representatives of the series with \(R\) = \(C_5H_{11}-C_8H_{17}\) are suggested as precipitants of Cu(II) in purification processes of model waste waters in a neutral medium [2].

It was of interest to investigate the complex formation and regularities of recovery of nonferrous metal ions from ammonia solutions, which are more difficult for purification, with homologues of this series (\(R\) = \(C_8H_{17}, C_{10}H_{21}, C_{12}H_{25}, C_{14}H_{29}\)) in processes of precipitation and ion flotation.

**EXPERIMENTAL**

\(N\)-(2-hydroxyethyl)alkyl amines were synthesized according to the known method [2]. The content of the main substance in the samples was determined by potentiometric titration similarly to amines [3]. It was no less than 96%. The values of \(pH\) were measured using the I-160M ionometer with glass and silver chloride electrodes, and conductometric titration was performed using the OK-102/1 conductometer with an OK-0902R electrode. The IR spectra of compounds were recorded using the IFS-66 Fourier spectrometer (Bruker, Germany). The detection conditions were as follows: milling in an agate mortar, suspension in Vaseline oil, resolution of 1 cm\(^{-1}\), and 100 scans. Derivatograms were recorded using a METTLER TOLEDO TGA/DSC 1 derivatograph. The elemental analysis was performed using a CHNS-932 analyzer of carbon, hydrogen, nitrogen, and sulfur (LECO Corp., the United States). Conditions of the complex formation of metal ions with HEA were studied by the precipitation method. We used aqueous solutions of Cu(II) and Co(II) sulfates and Ni(II) chloride. The ammoniac medium was formed by 0.01, 0.1, and 1.0 mol/L ammonia solutions. Reagents were added in the form of \(1 \times 10^{-2}\) mol/L solutions in ethanol. The interaction between the recovered metal ions and HEA was accompanied by the formation of precipitates, which were filtered through a blue-ribbon filter. The residual Cu(II) content in aqueous solutions was determined by the degree of their precipitation from the solution. The experiments on the investigation of the ion flotation and the flotation installation are described in [7]. We used the solutions of reagents in 0.1 mol/L HCl as collectors.
RESULTS AND DISCUSSION

The complex formation of Cu(II), Ni(II), and Co(II) ions with HEA was studied by the example of N-(2-hydroxyethyl)dodecyl amine (HDA). The reagent precipitates the metal ions most completely in the following ranges of pH (Fig. 1): Cu(II) 6.0–10.5, Co(II) 9.0–10.5, and Ni(II) 10.6–11.3. The maximal recovery was, %, Cu(II) 99.98, Co(II) 99.90, and Ni(II) 99.90; residual concentrations in the filtrate were, mg/L, Cu(II) 0.01, Co(II) 0.07, and Ni(II) 0.06. With an increase in the ammonia content, the degree of recovery of metal ions noticeably decreases due to the competitive reaction of formation of corresponding ammoniac complexes. For the maturation of the complexes, 10 min is sufficient.

To establish the composition of the complexes, we used the saturation method in the variant of conductometric titration (the example for Cu(II) is represented in Fig. 2). It follows from Fig. 2a that, as HDA is added to the solution of Cu(II) ammiate, complexes with ratios [Cu(II)] : [HDA] = 2 : 1, 1 : 1, and 1 : 2 are revealed. For the inverse titration of HDA by the ammonia solution of the Cu(II) salt, we found the ratios [Co(II)] : [HDA] = 1 : 1 and 1 : 2 (Fig. 2b). Conductometric titration showed that complexes with ratios [Co(II)] : [HDA] = 1 : 1 and 1 : 2 and [Ni(II)] : [HDA] = 1 : 1 and 1 : 2 are formed.

We preparatively isolated complexes of metal ions with HDA from ammoniac solutions with ratios [M(II)] : [HDA] found by conductometry. All isolated complexes were finely dispersed powders colored as follows: complexes of Cu(II) were violet, complexes of Co(II) were dark blue, and complexes of Ni(II) were pale green.

According to the data of thermal analysis, complexes of Cu(II) are stable up to 160°C and completely mineralize at \( T > 500°C \). The elemental analysis and IR spectroscopy did not allow us to make an unambiguous conclusion about the composition of the complex isolated with a ratio of 1 : 1. The results of the elemental analysis of the complex isolated with a ratio of 1 : 2