Research Article

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Fabrication of an innovative phosphonate Schiff base adsorbent for molybdenum adsorption and its applications for molybdenum adsorption from spent hydrodesulfurization catalyst

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Abstract

BACKGROUND: To investigate the recovery of molybdate from water and hydrodesulfurization catalysts, a novel synthesized phosphonate Schiff base, 4,4′-(((2,2-dimethylpropane-1,3-diyl) bis(azaneylylidene)) bis(methaneylylidene)) bis(2-methoxyphenol) (HMI) and 4-(((3-((4-(((S)-hydroxyhydrophosphoryl)oxy)-3-methoxybenzylidene) amino)-2,2-dimethylpropyl)imino) methyl)-2-methoxyphenyl hydrogen phosphonate (HIMP), was utilized. This study aimed to assess the structural and property aspects of this synthesized compound using diverse characterizations, including FTIR, Thermogravimetric Analysis (TGA), mass spectrometry (GC–MS), fluorescence transfer spectra, scanning electron microscopy (SEM), and ^{1}H-NMR, ^{13}C-NMR, and ^{31}P-NMR.

RESULTS: The study systematically examined several factors controlling molybdate recovery, including temperature, adsorbent dosage, pH, interaction time, and molybdate concentration using the batch technique. Optimal sorption effectiveness was achieved at pH 2, with an interaction time of 40 min, a 0.06 g adsorbent dose, at ambient temperature. The newly devised adsorbent exhibited an impressive adsorption capacity (Qe) of 372.54 mg of Mo per gram, with empirical data fitting the Langmuir and D-R adsorption models. The kinetics of molybdate uptake followed second-order kinetics. Thermodynamic aspects, including ΔG°, ΔS°, and ΔH°, were also investigated, providing appreciated perceptions into the energetic dynamics of the sorption process. Additionally, molybdate adsorption in the occurrence of other ions was explored, highlighting the selectivity of the modified phosphonate Schiff base for molybdate removal.

CONCLUSION: The study underscores the potential of the modified phosphonate Schiff base as a crucial adsorbent for molybdate elimination from both solutions and spent hydrodesulfurization catalysts. The findings offer important insights into the adsorption kinetics, thermodynamics, and selectivity of the adsorbent, enhancing our understanding of molybdate recovery processes and their broader applications.

Keywords: recovery; Schiff base; molybdenum; phosphonate derivative; spent catalyst

INTRODUCTION

Molybdenum, an important trace element, is crucial for various biological functions, including nitrogen fixation.[1] Molybdenum deficiency is commonly reported, while excessive levels can be detrimental, causing secondary copper deficiency and health issues like anemia, hypothyroidism, bone and joint abnormalities, delayed growth, and infertility.[2] Due to these risks, it is recommended by the World Health Organization that molybdenum concentrations in drinking water should not exceed 70 μg L^{-1}.[3] Molybdenum is commonly present in natural minerals like jordisite, molybdenite, ferrimolybdate, and wulfenite. Its high melting point, temperature resilience, corrosion resistance, and thermal conductivity make it extensively used in semiconductors, lubricants, catalysis, alloys, optoelectronics, corrosion inhibitors, fertilizers and pigments.[4,5]

Molybdenum (Mo) has an essential role in all living organisms as a cofactor in enzymes, making it essential for bacteria, plants, and animals,[6] alongside its unique geochemical properties. Due to its exceptional characteristics such as a high melting point, elevated temperature strength, thermal conductivity, and corrosion resistance, molybdenum (Mo) finds wide applications in various industrial processes.[7] Its industrial significance is considerable.[8] Mo catalysts are extensively used in petroleum desulfurization to reduce sulfur dioxide emissions from fuel combustion across

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