

Selective Sorption Of Pentavalent Vanadium Ions From Aqueous Solutions Using V(v)-Ion-Selective Imprinted Polymer

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Abstract

A novel V(v)-Ion-Selective Imprinted Polymer (ISIP) based on polyacrylamide and alginic acid is synthesized from an aqueous medium. Techniques viz. FTIR spectroscopy and PXRD analysis were used to characterize the polymer synthesized. The effect of concentration on sorption was investigated and optimized by the batch equilibration method. The selective sorption of V(v) ions from ternary solutions along with a competing metal ion species was investigated by the competitive adsorption method and found to be highly appealing for the selective adsorption-based removal of V(v) ions from aqueous solutions.

Keywords: ISIP, Sorbent, Selectivity, Adsorption

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I. Introduction

Vanadium is the second most abundant transition metal found in seawater [1]. It is the one which is the 20th most abundant element in the continental crust [2]. Being a biologically essential element it supports processes such as bacterial vanadium-dependant nitrogenases or haloperoxidases [3], respiration [4], and bioaccumulation in three groups of species [5]. On the other side concerns regarding the negative shade of vanadium over living organisms arises. It is reported that vanadium exposure can cause mitogen-activated protein kinase leading to neuroinflammation causing neurotoxicity and oxidative stress in brain cells [6]. Also, milder and more acute exposure can lead to gastrointestinal issues, skin and eye irritation, pain, pneumonia, and cardiovascular diseases. Various methods have been introduced for the selective removal of vanadium from different mediums to avoid or reduce its negative impact in different respects. Recent research reveals the possibility of highly selective ion-imprinted sorbent polymers. H.N Mohsen et al. synthesized a novel Vanadium ion-imprinted which can be used in the selective separation of V(IV) ions from crude oil [7]. S Dadfarnia reported the synthesis of a vanadium ion-imprinted polymer with *N*-benzoyl-*N*-phenyl hydroxyl amine using 4-vinyl pyridine as the monomer, ethylene glycol dimethacrylate as the cross-linker and 2,2'-azobis(isobutyronitrile) as the initiator with a maximum sorption capacity of 26.7 mg/g at pH 4.0 [8].

In this study, a V(v)-Ion-Selective Imprinted Polymer (ISIP) based on polyacrylamide and alginic acid has been synthesized. The factors affecting the selective sorption of V(v) ions were optimized by the batch equilibration method. Finally, the optimized conditions were applied for investigating the selectivity of V(v)-ISIP towards V(v) ions from a mixture with other interfering metal ions.

II. Materials and Methods

2.1 Materials

All materials used were of analytical and spectral grade. Monomers viz. Alginic acid and Acrylamide; initiator Potassium persulphate and the template ion source Ammonium metavanadate were obtained from NICE India.

The functional groups in the polymer synthesized and binding of V(v) on it were analyzed by Perkin Elmer 400 Fourier Transform IR (FTIR) spectrophotometer in the range 400-4000cm⁻¹. The sorption and selectivity studies were followed by Shimadzu 1200 UV-Vis spectrophotometer. The powder XRD analysis was carried out using an Aeris Research benchtop X-Ray Diffractometer.

2.2 Methods

2.2.1 Synthesis of V(v)-Ion-Selective Imprinted Polymer

Polymer is synthesized by free radical polymerization using suspension polymerization technique using water as reaction medium. 15.26g of alginic acid was mixed with 2g ammonium metavanadate in distilled water.

To the mixture add 10.6g acrylamide and 0.3g potassium persulphate. The polymerization is carried out at 70^o C with constant stirring until the polymerization completes and the polymer is allowed to settle down. The obtained V(v)-ISIP is washed thoroughly with distilled water for removing unreacted monomers. It is then dried, sieved, and weighed.

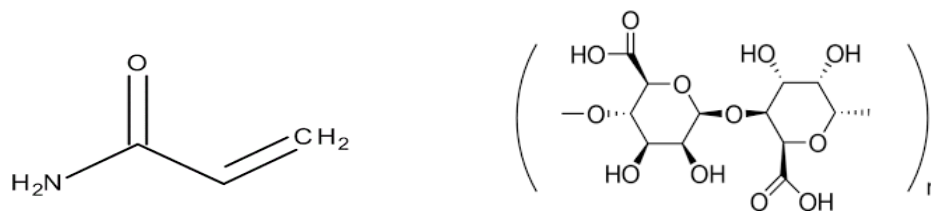


Figure 1: Monomers of the ISIP

2.3 Experimental techniques

2.3.1 Optimization of the effect of initial concentration

The effect of concentration on binding was investigated by batch-wise metal ion binding carried out at various concentrations. 100mg of the ISIP was equilibrated with (20 mL, 0.002-0.01N) V(v) ion solutions, and from the difference in concentration of template metal ion solution before and after equilibration, the amount of metal ion bound was determined by UV-Vis spectrophotometric method.

2.3.2 Selectivity study of ISIP

Selective sorption of metal ions on the ISIP was investigated by equilibrating ISIP with a mixture of Ce(IV) ion and Zn(II), Mg(II), Cr(VI), and V(V) ion solutions. The amount of metal ions adsorbed by ISIP was determined by UV-Vis spectrophotometry.

III. Results and Discussion

3.1 FTIR Spectra

The FTIR spectra of both ISIP and its V(v) complex are analyzed. The peak for C=O str observed at 1604cm⁻¹ is found to be shifted to 1589cm⁻¹. The symmetric stretching peak of C-O was observed at 1732cm⁻¹ in ISIP but was found at 1735cm⁻¹ in its V(v) complex. This observation divulges that the alginate carboxyl group participates in the V(v) ion adsorption process. Certain peaks are observed in the region below 1000 cm⁻¹ that can be due to the metal-Oxygen bond in the V(v) complex of ISIP.

3.2 PXRD Analysis

The powder XRD of the ISIP and its V(v) complex are analyzed and is given in the figure:2. The same XRD pattern was observed for both the polymer matrix and its metal complex. From this information, it could be concluded that as the V(v) ion binds to the polymer matrix, no change in the physical structure occurs.

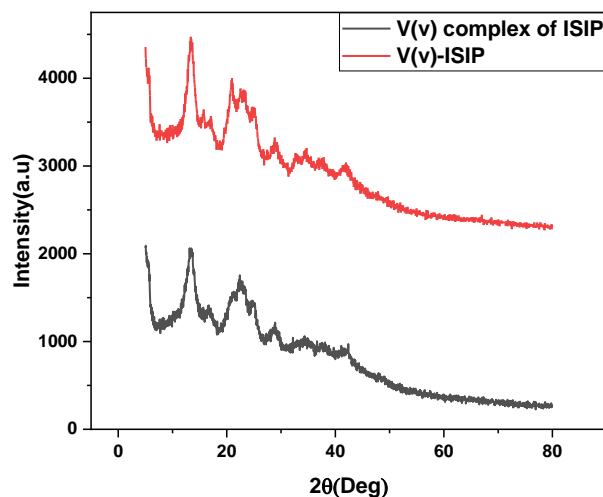


Figure 2: PXRD Pattern

3.3 Optimization of the effect of initial concentration

The effect of concentration on the sorption of V(v) ions by V(v)-ISIP was investigated by batch equilibration. A fixed amount (100mg) of V(v)-ISIP was shaken with varying concentrations (0.002-0.01N) of V(v) ion solution batch-wise. The amount of V(v) ion uptake was determined UV-Vis spectrophotometrically. From Figure 3, the amount of V(v) ion uptake increases gradually with an increase in V(v) ion solution. The difference in the concentration of V(v) ions in the bulk solution and on the surface of the V(v)-ISIP leads to the formation of a mass transfer driving force which reason the increase in ion uptake with the increase in V(v) ion solution concentration [9].

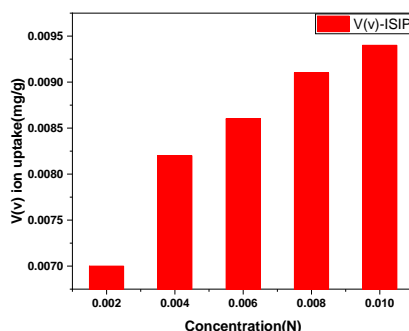


Figure 3: Effect of concentration

3.4 Selectivity study of ISIP

The specific affinity of V(v)-ISIP towards V(v) ions was studied by the competitive adsorption method. Zn(II), Mg(II), Ce(IV), and Cr(VI) were selected as the competing ions. The concentration of V(v) and competing ions were 0.3N. the selectivity is represented in Figure 4. From the data obtained Table 1, confirms that V(v)-ISIP possesses cavities exactly suitable for preferential adsorption of V(v) ions.

Competing metal ion	V(v) ion uptake mg/g	Competing metal ion uptake mg/g
V(v) and Ce(IV)	0.00935	0.0049
V(v) and Zn(II)	0.00903	0.0010
V(v) and Mg(II)	0.00910	0.0011
V(v) and Cr(VI)	0.0089	0.0000

Table 1: Selectivity study of ISIP

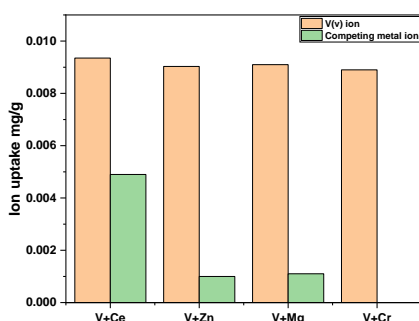


Figure 5: Selectivity study of ISIP

IV. Conclusions

A novel V(v)-ISIP is synthesized and the characterization data confirms the effectiveness of the synthesis. Before the selectivity study the effect of concentration on V(v) ion binding is investigated and found to be a favoring factor and is optimized. The selectivity study reveals the possibility of ISIP as an efficient sorbent for the selective sorption of V(v) ions from aqueous solutions in the presence of other metal ions.

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