Synthesis and characterization of low-cost ion-exchange resins used for the removal of metal ions

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ABSTRACT

Phenolic-formaldehyde resin (PFR) is used bad-tempered protecting agent in blending of different percentage by weight of Sulphonated Abutilon indicum, Linn. carbon (SAIC), we provide a synopses of selective metal ions, we provide a synopsis of selective metalions, regeneration level of Mg²⁺, Mg²⁺, Zn²⁺, and Pb²⁺. Thermodynamic equilibrium constants (ln KӨ) are calculated for Zn²⁺, H⁺ ion exchanges using the composite resins and also the thermodynamic parameters such as ∆H°, ∆G°, ∆S° are evaluated from Van't Hoff plot. The cation exchange capacity (CEC) of the composites were found to decreased with the increasing the percentage of SAIC in PFR matrix. It was observed that the composites up to 20 % (w/w) blending of SAIC2 retain all the properties of original PFR. Hence, the blended composites could be used as low cost ion exchangers when SAIC partially replaces the original PFR up to 20 % (w/w) SAIC2 blending without affecting the physico-chemical, thermal, spectral properties and CEC values of PFR.

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1. Introduction

The quality of water is of fundamental concern to mankind, since it is directly linked with human benefit. The water pollution and its impact on the environment are currently the focus of international attention. In developed nation are using dynamic methods to manage and prevent the environmental pollution caused by chemicals, but the developing countries are beginning to follow it. Most of the industries discharge the wastewater from some stage of their manufacturing processes. The indiscriminate disposal of untreated wastewater from various industries into the rivers or onto the domestic invariably pollutes surface/ground water and land. The contaminants in wastewater vary depending on the type of industry and nature of processes. The universal pollutants encountered in the industrial wastewater are soluble organics/inorganics, suspended solids, heavy metals, volatile materials, nitrogen, phosphorous, oil and greases. In the wastewater treatment, usually a decreasing the level of pollutants is achieved. A large number of methods have been used for the removal of harmful organic and inorganic constituents from wastewater. The available systems to treat wastewater can be broadly classified into physico-chemical and biological treatments. The selection of wastewater treatment process depends upon the nature of pollutants present in wastewater and quality of water required after the treatment process.

Ion exchange method is an appropriate technique, which could be employed under field condition for the removal of ionic materials from water and wastewater (Boito et al. 1987). Ion-exchange process finds a valuable place in the treatment of metal wastes from plating and other industrial processes. Many viable resins are originated from petroleum products and there is a continual increase in their cost. Hence, there is an urgent need to find out the new low-cost ion exchange resins (IERs) and reduce its cost by blending it with sulphonated carbons (SCs) prepared from carbonaceous materials. Such types of low-cost ion exchangers can be prepared by blending cheaper and freely available plant materials containing Phenolic groups. Attempts have also been made to prepare cheaper cationic resins from waste materials and natural products. The application of low-cost adsorbents obtained from agricultural by-products is widely used in the recent research as a replacement for costly conventional methods of removing heavy metal ions from wastewater (Homagai. 2012). Earlier studies have shown that the cheaper condensate ion exchangers could be prepared by partially blending the macroporous phenol-formaldehyde sulphonic acid resin (PFR or PFSAR) matrix by sulphonatedcarbon (SCs) prepared from coal (Sharma et al.1980), Egyptian corn cop (Metwally et al. 1992), bagasse charcoal (Swamiappan et al. 1984), Egyptian bagasse pith (Metwally et al. 1994), ground nut shell (Chandrasekaran et al. 1987), wheat husk (Dheiveesan et al. 1998), spent tea and mangoes bark (Krishnamoorthy et al. 1997), starch (Farag et al. 1995), jute (Hassan. 2003), Accianionilota (Kannan et al. 2003), cashew nut shell (Bato et al. 2003) and lignin (Zoumpoulakis et al. 2001). A careful literature survey revealed that no work has been done with Abutilon indicum. Abutilon indicum (local name; peelybooti or karandi) isa rigid, timbered, shrubby plant. It is widely distributed in the tropical countries (Kirtikar et al. 1980). It is known as “Albala” in Hindi and found in the outer Himalayan tracts from Jammu to Bhutan up to an altitude of 1500m and extending through the whole of northern and central India (Rajurkar et al. 2009).

The present work is to synthesize and characterize (by IR, TGA, and SEM studies) the new condensate / low-cost ion exchangers of PHOH – HCHO type blended with sulphonatedAbutilon indicum, Linn.Carbon (SAIC) and to estimate the physico - chemical properties including the cation exchange capacity (CEC) for some selective metal ions. The effect of particle size of selective metal ions, regeneration level of Mg²⁺ ions loaded IERs by using NaCl and to find out thermodynamic parameters for the above ion exchange process.

2. Materials and methods

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2.1. Materials

Abutilon indicum, Linn. (AI) was used as a plant material and it is easily available in India. It belongs to the family Malvaceae and called ‘Karandi’ in Tamil and Atibalain Hindi. The plant material was nearby collected, cleaned, dried and cut into small pieces of about 0.5cm length. Phenol and formaldehyde (AR) were purchased from Fischer reagents (India). Concentrated sulphuric acid (Sp.gr. = 1.82) and other chemicals/reagents used were produced from SD fine chemicals, India.

2.2. Methods

Abutilonindicum, Linn. plant material (500 g) has been carbonized and sulphonated by using con. sulphuric acid, washed with distilled water to remove excess free acid (tested with BaCl<sub>2</sub> solution) and dried at 70 °C for 12 h. It was labeled as SAIC.

Pure phenol–formaldehyde resin was prepared according to the literature method (Ramachandran et al. 1984; Radhakrishnan et al. 1990). It was then ground, washed with distilled water and finally with double distilled (DD) water to remove the excess acid (tested with BaCl<sub>2</sub> solutions), dried, sieved (210 μm) using Jayant sieves (India) and preserved for characterization (Kannan et al. 2003; Dheiveesan et al. 1988). It was labeled as PFR.

The condensates were obtained as per the method reported in the literature (Krishnamoorthy et al. 1997). The products with 10, 20, 30, 40 and 50 % (w/w) of SAIC in the condensates were labeled as SAIC1, SAIC2, SAIC3, SAIC4, and SAIC5 respectively. A separate sample of SAIC was also subjected to the characterization (instrumental and physico-chemical) studies.

2.3. Characterization of samples

2.3.1. Instrumental studies

FT-IR spectral data of pure resin (PFR), condensate with 20 % (w/w) of SAIC2 and pure SAIC were recorded using a JASCO FT-IR 460 plus FT-IR spectrophotometer by using KBr pellets. To establish the thermal degradation of the samples, TGA and DTA traces were obtained using the thermal analyzer. SEM analysis of pure resin (PFR), condensate with 20 % (w/w) of SAIC2 and pure SAIC were obtained using Hitachi Scanning Electron Microscope (Model S-450), Japan.

2.3.2. Physico-chemical characteristics

Samples were crushed and sieved into a particle size of 210 – 300 μm using Jayant sieves (India). This was used for further characterization by using standard procedures (Kannan et al. 2003; Chandrasekaran et al. 1987) to find out the values of absolute density (wet and dry), the percentage of gravimetric swelling and percentage of attritional breaking. The solubility of these IERs was tested with various organic solvents and inorganic reagents.

The values of cation exchange capacity (CEC) were determined by using standard titration technique (Ramachandran et al. 1984), as per the reported method (Raghunathan et al. 1984; Bassett et al. 1989). The effects of initial concentration of metal ions, particle size, chemical and thermal stability of the resin on CEC were determined (Kannan et al. 2003; Chandrasekaran et al. 1987; Krishnamoorthy et al. 1997).

After the exchange of H<sup>+</sup> ions by the Mg<sup>2+</sup> ions, the regeneration level of the condensates loaded with Mg<sup>2+</sup> ions were determined by using NaCl (brine) solution. The equilibrium constant (K<sub>exch</sub>) of an exchange reaction between H<sup>+</sup> ions (bound resin) and Zn<sup>2+</sup> ions (in aqueous solution) were obtained as per the literature method (Bato et al. 2003). Thermodynamic parameters (ΔG°, ΔH° and ΔS°) were computed by following the standard procedure and interpretation.

3. Results and discussion

3.1. Synthesis of composites

The experimental (observed) and theoretical (calculated) composition of SAIC in the condensates (SAIC1 – SAIC5) is in good agreement with each other. The results are similar to those obtained by others (Vasudevan et al. 1978; Sharma et al. 1980). This indicates that the preparative methods adopted for the synthesis of PFR and its condensates (SAIC1 – SAIC5) are more dependable and reproducible. Exactly 11.5mL of formaldehyde, 12.5mL of conc. Sulphuric acid and 10mL of phenol are found to be optimum.

3.2. Characterization by instrumental studies

FT-IR studies were used to confirm the ion exchangeable groups present in the IERs based on various stretching frequencies. Fig.1 (a and b) indicates the appearance of absorption bands at 1033 – 1035 cm<sup>-1</sup> (S = O str.), 1118 – 1186 cm<sup>-1</sup> (SO<sub>3</sub> sym. str.) and 623 – 673 cm<sup>-1</sup> (C-Str.) in pure resin (PFR), condensate resin with 20 % (w/w) of SAIC2 and pure SAIC, which confirm the presence of sulphonic acid group.

![Fig.1. FT-IR spectra of (a) PFR (b) condensate resin with 20 % (w/w) of SAIC2 and (c) pure SAIC (100 %).](Image)
concludes the presence of –CH₂ group in the samples. The weak absorption band at 887 – 894 cm⁻¹ (C-H def.) in the sample indicates that the phenols are tetra substituted. Thermogravimetric analysis (TGA) is used for rapidly assessing the thermal stability of various substances (Sharma et al. 2001). The consequences of TGA curves are shown in Fig.2. From the TG data summary, the 16 % weight loss of PFR sample and the 14 % weight loss 20 % (w/w) of SAIC2 for up to 90 °C observed. It is clearly shown that the loss of moisture absorbed by the resin and composite SAIC2. The temperature between 100 °C-300 °C there is 27 % weight loss in PFR and 30 % weight loss for SAIC2. Up to 360 °C, approximately 44 % loss of weight was observed for both PFR and SAIC2. It is clearly observed that up to 100 °C weight loss of resin is due to the removal of water content present in the resin. Beyond this temperature, a gradual chemical degradation of PFR and composite resin (PFR-SAIC2) occurs in 100 – 300 °C and up to 360 °C temperature range. Thermal studies indicate that the IERs are thermally stable up to 10 °C.

In Fig. 2a DTA curve shows that there are two peaks obtained in PFR, approximately at 60°C and 280°C. At 60 °C the presence of broad peak indicates the dehydration process of PFR. A peak at 280 °C shows the chemical changes, which occur due to thermal dehydration of PFR and reflects approximately 44 % weight loss in PFR. DTA curves of composite with 20 % (w/w) of SAIC2 (Fig. 2b) show that the two exothermic peaks are obtained at 70 °C and 290 °C respectively, which is comparable to PFR. The first peak shows the dehydration of SAIC2 and second sharp peak indicates the chemical changes arising because of thermal degradation of the condensate SAIC2.

SEM photos of PFR (Fig. 3a and b), condensate SAIC2 (Fig. 3c and d) and pure SAIC (Fig. 3e and f) with the magnification of 50 µm and 500 µm are given. SEM images that all the samples are macro permeable in nature. The high macro porous carbon obtained from Abutilon indicum, form the basin in which the phenol-formaldehyde sulphonic acid particles are deposited. As a result, the pore diameter decreases in condensate SAIC2 as compared to pure SAIC. Therefore, the condensate resin SAIC2 has a great mechanical strength and little attritional breaking (Fig. 3) compared to pure SAIC.
3.3. Physico-chemical characteristics

3.3.1. Absolute density

Absolute density value (Table 1) decreases from pure resin (PFR) to the condensate containing highest percentage (w/w) of SAIC5 (50 %) and then finally to pure SAIC (100 %). The density of condensate resin in dry (dehydrated) and wet (hydrated) form depends upon the structure of resin, degree of cross-linking and its ionic nature (Sharma et al. 2001). As expected, the value of absolute density decreases with the increase in SAIC content (% w/w) in the condensate. The value of high absolute density (in both dry and wet condition) indicates a high degree of cross-linking and hence suitable for making columns for treating polar and nonpolar effluents liquids of high density. The values of absolute density of the resins in the dehydrated states are slightly higher than that of the hydrated state, but somewhat close to each other. Moreover, the values of absolute density in wet and dry states are close to each other indicating that the pores of the sample may be macroporous in nature (Krishnamoorthy et al. 1997) and close packing.

<table>
<thead>
<tr>
<th>Sample</th>
<th>% of SAIC in IER</th>
<th>Density (g mL⁻¹)</th>
<th>Gravimetric Swelling</th>
<th>Attritional Breaking</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFR</td>
<td>0</td>
<td>2.015</td>
<td>80.37</td>
<td>9.00</td>
</tr>
<tr>
<td>SAIC1</td>
<td>10</td>
<td>1.778</td>
<td>65.68</td>
<td>18.25</td>
</tr>
<tr>
<td>SAIC2</td>
<td>20</td>
<td>1.604</td>
<td>55.82</td>
<td>19.52</td>
</tr>
<tr>
<td>SAIC3</td>
<td>30</td>
<td>1.435</td>
<td>54.29</td>
<td>24.36</td>
</tr>
<tr>
<td>SAIC4</td>
<td>40</td>
<td>1.257</td>
<td>44.71</td>
<td>31.25</td>
</tr>
<tr>
<td>SAIC5</td>
<td>50</td>
<td>1.195</td>
<td>42.20</td>
<td>38.65</td>
</tr>
<tr>
<td>SAIC</td>
<td>100</td>
<td>1.025</td>
<td>35.04</td>
<td>47.00</td>
</tr>
</tbody>
</table>

3.3.2. Gravimetric swelling

The value of gravimetric swelling percentage (Table 1) decreases from PFR (80.37 %) to SAIC (35.04 %). The average percentage of gravimetric swelling of the resin decreased with increasing SAIC content in the condensate. The values of gravimetric swelling percentage are found to be 80.37, 65.68 and 55.82 respectively, for 10, 20 and 30 % (w/w) blending of SAIC with the parent resin, viz., PFR. This indicates that up to 20 % (w/w) SAIC2 could be mixed with the PFR without affecting its property. The rigidity of the resin matrix is proved from the swelling measurements. Therefore, the cationic resin with higher SAIC content shows lower swelling, which reveals much lower rigid shape, and the rigidity decreases with the increase in the SAIC content in the condensate (Krishnamoorthy et al. 1997). It indicates that pure resin and condensates are rigid with non-gel macroporous structure (Bassett et al. 1989; Duraisamy et al. 1987).

3.3.3. Attritional breaking

Attritional breaking value in Table 1 percentage increases with the increase in SAIC content in the resins, representing the stability of the resin, which increases from pure resin to SAIC. Therefore, the mechanical stability is good up to 20 % (w/w) of SAIC2 with pure resin. This observation indicates that the capillary of the resin may be occupied by the sulphonated carbon (SAIC2) particles (Dheiveesan et al. 1988; Krishnamoorthy et al. 1997).

3.3.4. Solubility of IERS

The chemical stability of the samples in terms of its solubility in various solvents and reagents was determined. It reveals that PFR, condensates, and SAIC are practically insoluble in almost all the solvents and reagents. Therefore, these samples could be used as ion exchangers for treating non-aqueous effluents. However, the samples are found to be partially soluble in 20 % (w/w) NaOH solution, which indicates the presence of phenolic groups. Hence, these ion exchange materials cannot be used for the treatment of industrial effluents having high alkalinity. The insolubility of the samples even in the trichloroacetic acid express the rigidity, i.e., the high degree of cross-linking.

3.3.5. Cation exchange capacity

CEC data are given in Table 2. The CEC values decrease with the increase in the percentage (w/w) of SAIC in PFR for 0.1M solution of metal ions. CEC range (in m. mol. g⁻¹) for condensates 0-100 % (w/w) of SAIC with PFR: 1.4864 - 0.1791 for Na⁺ ion; 1.6216 - 0.2786 for K⁺ ion; 1.6875 - 0.8484 for Ca²⁺ ion; 1.6934 – 1.1968 for Cu²⁺ ion; 1.8111 - 0.6464 for Mg²⁺ ion; 1.7052 – 1.01 for Pb²⁺ ion and 1.8343 – 1.1312 for Zn²⁺ ion. Fig.4 shows the percentage CEC for various IERS-metal ion systems.

The Value of CEC for individual metal ion depends upon its atomic radius or atomic number. At the same time, the CEC value depends upon the anionic part of the metal salt, i.e., inter ionic forces of attraction between anions and cations, which plays a vital role in deciding the value of CEC for a particular metal salt solution (Natarajan et al. 1993; Dimov et al. 1990; Son et al. 2001). From the CEC data given in Table 2, the CEC of the samples is found to decrease in the following order,

\[ \text{Zn}^{2+} > \text{Pb}^{2+} > \text{Mg}^{2+} > \text{Cu}^{2+} > \text{Ca}^{2+} > \text{K}^+ > \text{Na}^+ \]

3.3.6. Selectivity of metal ions
The selectivity order of metal ions, i.e., orders of CEC value also depend upon the ionic potential and the hydrated atomic radius of the metal ions in solution (Dimov et al. 1990). The order of exchange affinities of various metal ions is not unique for all the ion exchange systems. Only under dilute conditions, Hofmeister series is applicable. But, under high concentration the order is different (Kunin, et al. 1958).

It is equally important to note that the relative behavior of these ions for other ionic phenomena is different from the attraction order under the chemical met hod requiring ion exchangers of the low cost ion exchangers. SAIC can be inexpensively prepared from the corresponding plant material (Abutilon indicum), which is freely available in plenty, in this study area viz., Tamil Nadu, India.

The observed order in the present study is different from that of the Hofmeister or lyotropic series. This may be due to the concentration of the metal ion in effluent solution, which is relatively high and also due to the selectivity of the metal ions. Therefore, each composite resin (prepared from plant material) system has its own specific selectivity of the particular metal ion.

### Table 2. Cation exchange capacity of PFR, pure SAIC and condensate SAIC1 – SAIC5 (H⁺) form of 0.1 M solution of selective metal ions at 303K.

<table>
<thead>
<tr>
<th>Sample</th>
<th>% of SAIC in IER</th>
<th>Cation exchange capacity, in m. mol. g⁻¹ 0.1 M solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFR</td>
<td>100</td>
<td>Na⁺: 1.4864, K⁺: 1.6216, Ca²⁺: 1.6875, Cu²⁺: 1.6934, Mg²⁺: 1.8111, Pb²⁺: 1.7052, Zn²⁺: 1.8343</td>
</tr>
<tr>
<td>SAIC1</td>
<td>10</td>
<td>Na⁺: 0.8509, K⁺: 0.9552, Ca²⁺: 1.5352, Cu²⁺: 1.4039, Mg²⁺: 1.5099, Pb²⁺: 1.5655, Zn²⁺: 1.6008</td>
</tr>
<tr>
<td>SAIC2</td>
<td>20</td>
<td>Na⁺: 0.8109, K⁺: 0.9253, Ca²⁺: 1.515, Cu²⁺: 1.3736, Mg²⁺: 1.515, Pb²⁺: 1.515, Zn²⁺: 1.5099</td>
</tr>
<tr>
<td>SAIC3</td>
<td>30</td>
<td>Na⁺: 0.7014, K⁺: 0.7711, Ca²⁺: 1.3584, Cu²⁺: 1.3029, Mg²⁺: 1.2625, Pb²⁺: 1.4443, Zn²⁺: 1.4796</td>
</tr>
<tr>
<td>SAIC4</td>
<td>40</td>
<td>Na⁺: 0.6865, K⁺: 0.7462, Ca²⁺: 1.1059, Cu²⁺: 1.2625, Mg²⁺: 1.11, Pb²⁺: 1.3988, Zn²⁺: 1.4392</td>
</tr>
<tr>
<td>SAIC5</td>
<td>50</td>
<td>Na⁺: 0.6169, K⁺: 0.597, Ca²⁺: 1.0049, Cu²⁺: 1.2322, Mg²⁺: 1.0504, Pb²⁺: 1.2019, Zn²⁺: 1.313</td>
</tr>
<tr>
<td>SAIC</td>
<td>100</td>
<td>Na⁺: 0.1791, K⁺: 0.2786, Ca²⁺: 0.8484, Cu²⁺: 1.1968, Mg²⁺: 0.6464, Pb²⁺: 1.01, Zn²⁺: 1.132</td>
</tr>
</tbody>
</table>

### 3.3.7. Effect of stability of IERs on CEC

The effect of different reagents and heat on the values of CEC for Mg²⁺ ions for various cationic resins is shown in Table 3. On treatment with 20 % (w/w) NaOH solution, 1.0 – 2.2 % reduction in CEC value is noted. Upon treatment of the resin with an organic solvent like benzene, the loss in CEC is noted to be 1.0 – 3.0 %. The decrease in CEC value on treatment with boiling water is 0.4 – 1.5 %, for condensates with different amounts of SAIC in the resin. When the resins are heated for 10 h at 100 °C the value of CEC decreases (8 – 18 %) compared to the resins, which are not heated. All these observations reveal that the condensates have good thermal and chemical stability.

### Table 3. Chemical and thermal effect on CEC of PFR and condensates for exchange with 0.1 M Mg²⁺ ions at 303 K.

<table>
<thead>
<tr>
<th>Reagents</th>
<th>Cation exchange capacity, in m. mol. g⁻¹ 0.1M solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFR</td>
<td>SAIC1: 1.855, SAIC2: 1.714, SAIC3: 1.535, SAIC4: 1.413, SAIC5: 1.345</td>
</tr>
<tr>
<td>20% (w/v) NaOH</td>
<td>SAIC1: 1.745, SAIC2: 1.613, SAIC3: 1.514, SAIC4: 1.343, SAIC5: 1.243</td>
</tr>
<tr>
<td>Benzene</td>
<td>SAIC1: 1.696, SAIC2: 1.656, SAIC3: 1.525, SAIC4: 1.315, SAIC5: 1.287</td>
</tr>
<tr>
<td>1M HCl</td>
<td>SAIC1: 1.768, SAIC2: 1.635, SAIC3: 1.498, SAIC4: 1.356, SAIC5: 1.298</td>
</tr>
<tr>
<td>Water</td>
<td>SAIC1: 1.808, SAIC2: 1.723, SAIC3: 1.541, SAIC4: 1.334, SAIC5: 1.302</td>
</tr>
<tr>
<td>Thermal treatment</td>
<td>SAIC1: 1.616, SAIC2: 1.532, SAIC3: 1.386, SAIC4: 1.132, SAIC5: 1.102</td>
</tr>
</tbody>
</table>

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CEC data given in Table 3, describe that the particle size of IERs < 210 μm are fine, 300 – 500 μm and > 500 μm are common as to cause very low value of CEC compared to 210 – 300 μm particle size. Hence, in order to have the effective CEC, the bed size and particle size of IER should be maintained and the recommended particle size of IER is 210 – 300 μm for preparing columns for ion exchange studies.

### 3.3.8. Regeneration of IERs

![Regeneration level for PFR condensates and SAIC by using NaCl after the exchange with Mg2+ ions.](image)

Fig. 5. Regeneration level for PFR condensates and SAIC by using NaCl after the exchange with Mg2+ ions.

The regeneration data obtained with 40 mL of 0.2 M NaCl (brine) solution conclude that it effectively regenerates PFR, condensate resins, and pure SAIC. Exactly 40 mL of 0.2M brine solution effectively acts as a regenerating agent for original PFR (Fig. 5). Most of the CRs are in Na+ form and hence 40mL of 0.2 M NaCl is to be used as a regenerator for every 2 g of the resin.

### 3.3.9. Equilibrium Constant and Thermodynamic Parameters

In order to determine the effect of temperature on the exchange of Zn2+ by SAIC2, experiments were carried between 303 K and 333 K. The thermodynamic parameters for the removal of Zn2+ by IER (SAIC2) were calculated using the following basic thermodynamic equations.

\[
\Delta G^0 = - RT \ln K_c
\]

\[\ln K_c = \Delta S^0/R - \Delta H^0/RT\]

Where R is the universal gas constant, 8.314 J/mol/K and T, the absolute temperature (K) and \( \Delta H^0 \), \( \Delta S^0 \) are the changes in enthalpy (J/mol), Gibb's free energy (J/mol) and entropy (J/K/mol) respectively. The values of \( \Delta H^0 \) and \( \Delta S^0 \) could be determined from the slope and intercept of the linear plot of lnKversus 1/T, where R is the gas constant, Kc is the equilibrium constant and T is the solution temperature in Kelvin. The thermodynamic parameters can be calculated from Vant Hoff plot (Fig. 6). The positive value of \( \Delta H^0 \) (6350J/mol) for the adsorption of Zn2+ by SAIC2 showed endothermic nature of the overall process. Negative \( \Delta G^0 \) value (-882 J mol\(^{-1}\)) indicates that the ion exchange reaction is spontaneous (Selvapandian et al. 2015).

### 4. Conclusions

From the current study, it is concluded that the PFR could be blended withupto 20 % (w/w) of SAIC2, without affecting its spectral, thermal and physico-chemical properties and also retain the CEC values of PFR. The effect of particle size and initial concentration of Zn2+ ions on CEC, its regeneration level by NaCl solution was studied. To have the effective CEC, the particle size of IER should be maintained between 210 and 300μm. CEC values of various metal ions of blends up to 20 % (w/w) SAIC2 were found to be very close to that of PFR. Equilibrium studies for the removal of Zn2+ ion reveal that the process is spontaneous, endothermic and occur with an increased randomness. SEM images have well defined micrometric structures. Therefore, the composites obtained from cationic matrix blending of PFR with 20 % (w/w) of SAIC2 will absolutely lower the cost which can be used in wastewater treatment, especially for the removal of metal ions.

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Fig. 6. Vant Hoff plot for the removal of Zn²⁺ by SCAC2.

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