Equilibrium and Kinetic Characteristics of Uranium Recovery by the Strong Base Ambersep 920U Cl Resin

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Abstract : *The equilibrium and kinetic characteristics of the strong base macroreticular resin, Ambersep 920U Cl developed by Rhom and Hass for uranium (VI) adsorption from high saline solutions have been determined using a synthetic uranium solution. The adsorption parameters including pH, contact time, initial uranium (VI) concentration, temperature, diverse ions and chloride concentration have been optimized. The physical parameters including the adsorption kinetics, the isotherm models and the thermodynamic data have also been determined to describe the nature of the uranium (VI) adsorption by the working resin Ambersep 920U Cl. The adsorption capacity of uranium (VI) upon the latter under the optimum conditions has been found to attain 50 mg/g. Almost complete desorption of the adsorbed uranium (VI) has successfully been achieved with either 1 M H_2SO_4 acid solution or else with 0.6 M Na_2CO_3 solution. The realized capacity of the working resin has been found to agree with both the pseudo second order reaction and the Langmuir isotherm.*
Keywords: *Ambersep 920U Cl, Uranium Recovery. Adsorption, Desorption.*

I. Introduction

Uranium is one of the most important heavy metals because of its strategic importance in the energy field [1]. Traditional solvent extraction processes which require extensive amounts of organic solvents have been a basic method of uranium concentration[2]. This technique has often been referred to as being tedious and time consuming. A special attention is actually focused on those techniques which are characterized by a considerable reduction or complete elimination of organic solvents[3,4]. Among these techniques, solid-liquid extraction has proved to be more advantageous in view of their total insolubility of the applied solid in the aqueous phase, its low rate of physical degradation besides its high sorption capacity as well as its good flexibility and kinetic properties[5,6]. Many types of adsorbents have been synthesized and studied for the recovery and separation of uranium (VI) such as Alizaren Red-S modified anion exchange resin[7], a copolymer composed of acrylic acid (AA) and 2-acrylamide-2-methylpropane sulfonic acid (AMPS) crosslinked with N,N-methylene bisacryl amide[8] and crosslinked acrylic acid (AA) acrylonitrile (AN) copolymer resin[9]. A survey of the concerned literature indicates that uranium (VI) can be adsorbed as both the anionic complex species $[UO_2(SO_4)_2^{2-}]$ and $[UO_2(SO_4)_3^{4-}]$ by a strong base anion exchange resin or else as a uranyl cation UO_2^{2+} by a chelating ion exchange resin. Uranium (VI) adsorption using the low cost citrus biomass at pH 4[10] and Amberlite XAD-2 impregnated with cyanex-272 from the ore tailings of the complex oxide mineral uranmicrolite has given an uptake capacity of 41.76 mg/g[11]. The enrichment of uranium (VI) from monazite and the certified samples (USGS and GSP-1) by the chelating resin Amberlite XAD-2-ortho-vanillinthiosemicarbazone has also been studied[12]. In addition, the sorption of uranium from HNO_3 acid using TBP-impregnated activated carbon was studied to optimize the experimental adsorption conditions[13]. The pH plays an important role on the uranium (VI) adsorption by oxidized activated carbon and chitosan[14]. A commercial phosphonic acid resin, Tulsion CH-96 was also used to extract uranium (VI) from 4M HNO_3 acid medium with an uptake capacity of 70 mg/g[15]. Natural clays as zeolites[16] and manganese oxide coated sand[17] are also used to adsorb UO_2^{2+} from different matrices. Amberlite XAD-16 modified by bis-2-hydroxy benzyl-p-phenylene diamine (BHBPD) has indeed been used as a selective chelating resin for preconcentration of uranium (VI)[18]. A novel chelating resin, chloromethylated resin modified with thenoyl trifluoroacetone (TTA), was also applied for uranium (VI) selective adsorption with a maximum loading capacity of 138 mmol/g[19]. Also, uranium (VI) could be adsorbed using silica modified with both the xylenol orange of a loading capacity of 10 mg/g[20] and the new class of multi dentate ligand anchored with polymeric resin by grafting Amberlite XAD-16 with [2-(methyl-3-oxo-2-phenyl-2,3-dihydro-1H-pyrazolyl-4-carbamoyl)-ethyl]-phosphonic acid abbreviated as (AXAD-16-MOPPA) and which has a loading capacity of 1.45 mmol/g[21]. In the light of the above discussion, the present work in concerned with the determination of the equilibrium and kinetic characteristics as well as the interesting thermodynamic data of the strong base, Ambersep 920U Cl developed by Rhom and Hass for uranium (VI) recovery from high saline solutions using a synthetic uranium solution. This study has been found necessary to face such problems in all constituents where the mini Pilot Plant

processing the uraniferous Abu Zeneima ore material of South Western Sinai is suffering from using a conventional anion exchange resin. This situation has implied a prior through washing of the ore material to eliminate most of the chloride species; a matter which otherwise would increase the production cost besides possible losses of some uranium. To realize the objectives of this work, the various parameters of uranium (VI) adsorption upon the studied resin have experimentally been optimized as a pre-requisite for the determination of the relevant physical characteristics.

II. Experimental

Ambersep 920U Cl Preparation:

The strong base industrial grade Ambersep 920U Cl ion exchange resin of Rohm and Haas is essentially a macroreticular anion exchange resin that has been used in the present work to determine its equilibrium and kinetic characteristics for uranium (VI) recovery from a synthetic solution. It is actually a true macroporous network which differs completely from the conventional gel type resins and which provides an outstanding osmotic and physical stability as well as excellent kinetics. It was purchased from Across Organics and prior application, it was washed with distilled water followed by 0.5 M sulfuric acid for several times in turn and was then dried at 50°C.

Synthetic stock solutions:

A standard stock solution of 1000 mg/L uranium (VI) has been prepared by dissolving 1.782 g of uranyl acetate dihydrate $UO_2(CH_3COO)_2.2H_2O$ (Prolabo) in 1000 ml distilled water acidified with 2 ml conc. sulfuric acid. On the other hand, several standard stock solutions of 1000 mg/L of possible interfering ions during U (VI) adsorption by the studied resin have been prepared by dissolving suitable weights of their salts in 1000 ml distilled water.

Experimental procedure:

The batch procedure was performed to optimize the basic equilibrium conditions for uranium (VI) adsorption such as pH, contact time, initial uranium concentration, temperature and diverse ion tolerance. In these experiments, 50 ml of 150 mg/L uranium standard solution were mechanically mixed by stirring at 100 rpm with 0.1 g resin into a 100 ml conical flask. The mixture was shaken for a definite period of time at different temperatures. The amount of uranium adsorption q_e (mg/g) was calculated from the difference of uranium concentration in the aqueous solution before and after adsorption at the equilibrium time t according to the following equation:

$$q_e = \frac{(C_\circ - C_e)V}{W}$$

where C_0 and C_e are the liquid phase concentrations of uranium (VI) at initial and equilibrium time, respectively; V is the volume of the solution (L) and W is the mass of dry resin used (g)[22]. For the uranium desorption, different acids, alkalis and salts were studied as eluants for the adsorbed uranium (VI). Each experiment was performed by shaking 0.1 g of uranium-loaded resin with 5 ml of each individual eluant at different concentration for 60 minute contact time at room temperature.

Analytical procedures:

The quantitative analysis of uranium was carried out by a single beam spectrophotometer, Meterch Inc (SP-8001) using Arsenazo III indicator (Sigma-Aldrich)[23] and confirmed by an oxidimetric titration against ammonium metavanadate using N-phenyl anthranilic acid indicator (Sigma-Aldrich)[24,25] using the computerized titrator, SCHOTT instruments, GmbH, Germany. The latter was also used for the quantitative analysis of chloride ions by titration using the silver nitrate method[26].

The Inductively Coupled Plasma-Optical Emission Spectrometry, ICP-OES (Prodigy high dispersion ICP, TExxLEDYNE - Leeman Labs USA) was used to determine the tolerance limits of interferences of the studied diverse ions.

III. Results And Discussion

Optimization of uranium adsorption conditions:

Effect of pH:

The effect of pH on uranium uptake (mg/g) from the synthetic sulfate solution by Ambersep 920U Cl resin was studied in the range from 0.5 to 5 and in the absence of chloride ions while the other parameters were kept constant at 0.1 g resin, 50 ml acidic solution assaying 150 mg/L U (VI) concentration for 3 h contact time at room temperature. From the obtained results shown in Fig. (1), it is clearly evident that uranium uptake by the Ambersep 920U Cl resin has attained a maximum value of 50 mg/g at pH values ranging from 0.5 to 3.5.
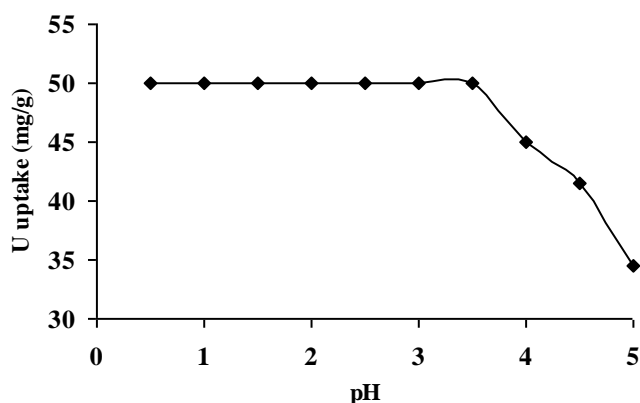
Figure (1): Effect of pH on uranium uptake using Ambersep 920U Cl.
(**Extraction conditions:** V: 50 ml, C_0: 150 mg/L (U), W: 0.1 g resin, T: 25ºC, contact time: 3 hours)

Effect of contact time:

The effect of contact time upon uranium uptake (mg/g) from 50 ml of the synthetic chloride-free sulfate solution assaying 150 mg U/L by Ambersep 920U Cl resin was studied in the range of 10 to 210 min. while the other extraction conditions were fixed at pH 2 and using 0.1 g of the working resin at room temperature. The obtained results plotted in Fig. (2) indicate that the uranium uptake has gradually increased with increasing the contact time till reaching the maximum value of 50 mg/g at 90 min. and remains constant thereafter. Hence, the adsorption equilibrium time considered for further work has been taken as 90 min.
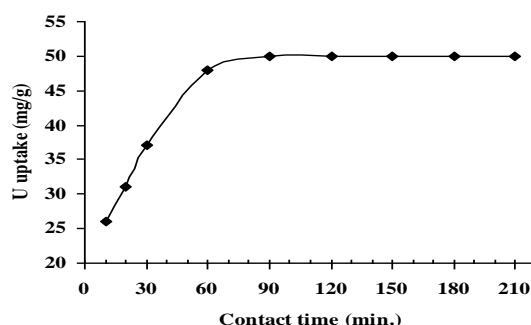

Figure (2): Effect of contact time on uranium uptake using Ambersep 920U Cl.
(**Extraction conditions:** pH:2, V: 50 ml, C_0: 150 mg/L (U), W: 0.1 g resin, T: 25ºC)

Effect of initial uranium concentration:

In absence of chloride ions, the effect of the initial uranium (VI) concentration on its adsorption upon 0.1 g of Ambersep 920U Cl resin was studied in the range from 10 to 300 mg/L while the other factors were kept constant at pH 2 for 90 min. contact time at room temperature. From the obtained data (Fig. 3), it is clear that the uranium uptake (mg/g) increases with increasing the uranium concentration till reaching the maximum uptake of uranium at 100 mg/L and which remains constant thereafter. Therefore, it can be ascertained that the maximum loading capacity of uranium upon Ambersep 920U Cl resin is 50 mg/g equivalent to 50 g/Kg resin.
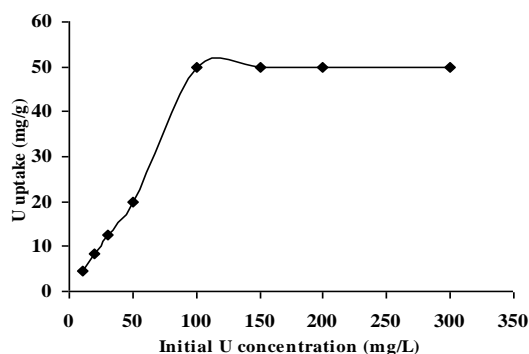

Figure (3): Effect of initial uranium concentration on uranium uptake using Ambersep 920U Cl.
(**Extraction conditions**: pH: 2, V: 50 ml, W: 0.1 g resin, T: 25ºC, contact time: 90 min.)

Effect of temperature:

The effect of temperature on the uranium uptake capacity of 0.1 g Ambersep 920U Cl resin from 50 ml solution assaying 150 mg/L in the absence of chloride ions was studied within the temperature range of 25 to 60 ℃ while the other factors were kept constant at pH 2 using 90 min. contact time. From the obtained results represented in Fig. (4), it is clear that the uranium uptake capacity by the working resin has decreased with increasing the temperature indicating that the U (VI) adsorption is of an exothermic nature in a manner to be favored at room temperature. The uranium uptake capacity which at room temperature (25 ℃) has attained 50 mg/g was decreased down to reach 31.5 mg/g at 60 ℃. This decrease in the uranium uptake capacity with increasing temperature might be due to a decreasing effect in the surface activity where at higher temperature, the thickness of the boundary layer would decrease due to the increasing tendency of U (VI) to escape to the solution phase.
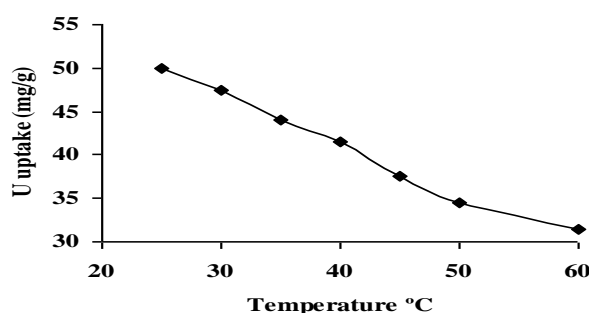

Figure (4): Effect of temperature on uranium uptake using Ambersep 920U Cl.
(Extraction conditions: pH: 2, V: 50 ml, C_0: 150 mg/L (U), W: 0.1 g resin, contact time: 90 min.)

Effect of interfering ions:

The effect of other ions on the adsorption of U (VI) upon Ambersep 920U Cl was studied using different solution of a binary mixture of uranium (VI) with one of the other studied diverse ions under the optimized conditions. The results shown in Table (1) indicate that the working Ambersep 920U Cl resin selectively adsorbs U (VI) in the presence of other diverse ions with an adequately high separation factor β ($\beta = D_u/D_m$) and a high tolerance limit. The D_U and D_M are the distribution ratio of uranium and the associated metal ion respectively.

Table (1): The effect of diverse ions on extraction of U (VI) using Ambersep 920U Cl.

Diverse ions	Tolerance limit, W/W*	% U (VI) Recovery	Separation factor, β**	Diverse ions	Tolerance limit, W/W*	% U (VI) Recovery	Separation factor, β**
Na^{2+}	2000	99	1×10^5	Cr^{3+}	300	99	1.6×10^5
K^+	2000	99	1×10^5	Ni^{2+}	300	98	1.6×10^4
Ca^{2+}	2000	99	1×10^5	Cu^{2+}	500	99	2.5×10^4
Mg^{2+}	2000	99	1×10^5	Zn^{2+}	300	98	1.6×10^4
Si^{4+}	2000	99	1×10^5	Fe^{3+}	500	98	5×10^3
Al^{3+}	2000	99	1×10^5	Zr^{4+}	250	98	1.2×10^4
Ba^{2+}	2000	99	1×10^5	Pb^{2+}	200	98	9.8×10^3
P^{5+}	2000	99	1×10^5	V^{5+}	500	99	2.5×10^4
Ti^{4+}	200	99	1×10^5	Mn^{2+}	300	99	1.6×10^4

(Extraction conditions: pH: 2, V: 50 ml, C_0: 50 mg/L (U), T: 25° C, W: 0.1 g resin, contact time: 90 min.)
* Weight ratio of the interfering ion to that of uranium (VI).

Effect of chloride concentration:

The effect of chloride ions on uranium (VI) adsorption by Ambersep 920U Cl is very important. During uranium adsorption upon the traditional anion exchange resins, it was found that the chloride ions compete and substitute the anionic uranium complex species; hence a reduction of uranium uptake would be manifested. To overcome this problem, a modified resin structure was developed by Rhom and Hass; namely Ambersep 920U Cl resin which would selectively adsorb uranium ions in the presence of relatively high chloride ions concentration. Accordingly, it was found necessary to study the effect of chloride ions on the uranium adsorption of Ambersep 920U Cl resin within the concentration range from 1 upto 50 g/L while the other factors were kept constant at the above mentioned optimum conditions but using 50 ml solution assaying 50 mg/L U (VI). From the obtained results, it is observed that a chloride concentration ranging from 1 to 30 g/L does not affect the uranium uptake capacity and which has slightly been decreased thereafter (Fig. 5).
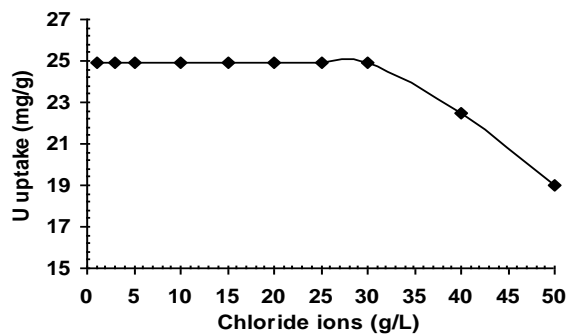
Figure (5): Effect of chloride concentration on uranium uptake using Ambersep 920U Cl.
(Extraction conditions: pH: 2, V: 50 ml, C_0: 50 mg/L (U), T: 25° C, W: 0.1 g resin, contact time: 90 min.)

Characteristics of the physical parameters:
Kinetic characteristics:

In order to investigate the kinetic characteristics concerning the mechanism of U (VI) adsorption upon Ambersep 920U Cl resin and the potential rate controlling steps such as mass transport, the pseudo-first order model and the pseudo-second order one were applied[27]. In the pseudo-first order equation:

$$Log\left(q_e - q_t\right) = Log q_e - \left(\frac{K_1}{2.303}\right)t$$

q_e is the equilibrium adsorption capacity (mg/g), and K_1 is the pseudo-first order rate constant (min.$^{-1}$). The plot of Log (q_t-q_e) against t gives a straight line plot as shown in Fig. (6), which suggests the applicability of the pseudo-first order kinetics model to fit the experimental data as given in Table (2). The calculated value of the adsorption capacity, $q_{e,cal.}$ is 73.8 mg/g which is higher than the experimentally determined capacity of 50 mg/g. On the other hand, in the pseudo-second order equation:

$$\frac{t}{q_t} = \frac{1}{K_2 q_e^2} + \left(\frac{1}{q_e}\right)t$$

K_2 is the rate constant of the pseudo-second order adsorption (g.mg^{-1}.min.$^{-1}$). The pseudo-second order plot of t/qt against t is graphically plotted in Fig. (7) which is also linear and with a correlation coefficient of 0.9947. However the calculated value of the adsorption capacity, $q_{e,cal.}$, of 51.2 mg/g is closer to the experimentally determined capacity; namely $q_{e, exp.}$ of 50 mg/g. Therefore, it could be suggested that U (VI) adsorption by Ambersep 920U Cl resin better follows the pseudo-second order model than the pseudo-first order model.

Table (2): Kinetic parameters of uranium adsorption on Ambersep 920U Cl.

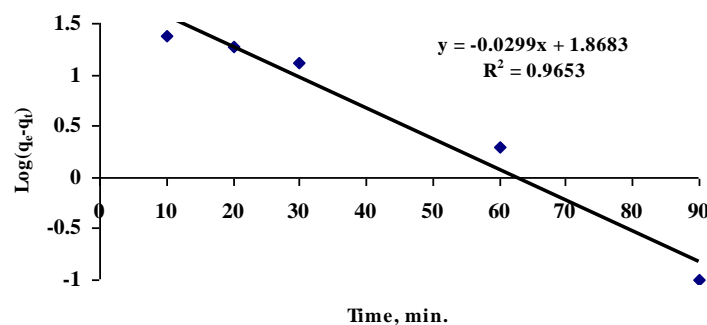| Resin	Experimental	Pseudo-first order			Pseudo-second order		
	$q_{e, exp.}$ (mg/g)	q_e, mg/g	K_1	R^2	q_e, mg/g	K_2	R^2
Ambersep 920U Cl	50	73.8	0.068	0.9653	51.2	0.0025	0.9947

Figure (6): Pseudo-first order kinetics of uranium adsorption on Ambersep 920U Cl.
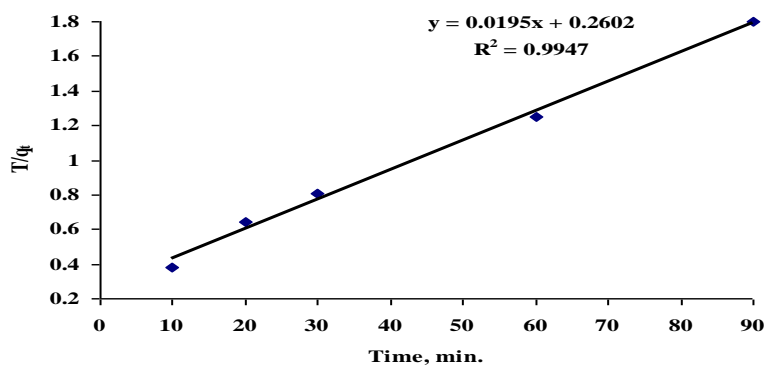**(Extraction conditions:** pH: 2, V: 50 ml, C_0: 150 mg/L (U), W: 0.1g resin, T: 25° C)

Figure (7): Pseudo-second order kinetics of uranium adsorption on Ambersep 920U Cl.
(Extraction conditions: pH: 2, V: 50 ml, C_0: 150 mg/L (U), W: 0.1g resin, T: 25° C)

Isotherm models:

The adsorption isotherm provides the most important information about how the adsorbed molecules are distributed between the solid and aqueous phases when the adsorption process reaches an equilibrium state. For this purpose, the uranium adsorption on Ambersep 920U Cl has been described by applying the most widely used Langmuir[28] and Freundlich isotherm[29] models. The Langmuir isotherm considers the adsorption as a chemical phenomenon with the formation of energetically mono layer with a maximum adsorption capacity of q_{max} (mg/g) through the following equation:

$$\frac{C_e}{q_e} = \frac{C_e}{q_{max}} + \frac{1}{K_L q_{max}}$$

where K_L is a constant of the adsorption equilibrium (L/mg), q_{max} is the saturated monolayer adsorption capacity (mg/g) while q_e and C_e are the uranium uptake capacity (mg/g) of adsorbent and the residual uranium concentration (mg/L) at equilibrium. A linearized plot of C_e/q_e against C_e gives q_{max} and K_L is shown in Fig. (8). On the other hand, in the empirical Freundlich equation based on adsorption on heterogenous surface:

$$Log q_e = Log K_f + \frac{1}{n} Log C_e$$

K_F and n are the Freundlich constants which represent the adsorption capacity and the adsorption intensity respectively. K_F and n can be determined from a linear plot of Log q_e against Log C_e (Fig. 9). The results of the Langmuir and Freundlich isotherm constants are given in Table (3) where it is found that uranium (VI) adsorption on Ambersep 920U Cl correlates quite well ($R^2 > 0.99$) with the Langmuir equation as compared with the Freundlich equation under the studied concentration range. Langmuir model is thus suitable for the description of the adsorption equilibrium of uranium (VI) onto Ambersep 920U Cl. The essential characteristics of the Langmuir isotherm can be expressed in terms of a dimensionless constant separation factor[30], R_L, which is used to predict if an adsorption system is favorable or not. The separation factor, R_L, is given by the following equation:

$$R_L = \frac{1}{1 + K_L C_0}$$

where C_0 is the initial uranium (VI) concentration (mg/L) and K_L is the Langmuir adsorption constant (L/mg). Table (4) lists the calculated results of the R_L values for uranium (VI) concentration ranging from 10 to 300 mg/L. Based on the effect of separation factor on the isotherm shape, the R_L values are in the range of $0 < R_L < 1$, which indicates that the adsorption of uranium (VI) on Ambersep 920U Cl is favorable.

Table (3): Langmuir and Freundlich isotherm model constants for Ambersep 920U Cl resin.

Practical capacity, q_e, (mg/g)	Langmuir isotherm model			Freundlich isotherm model		
	q_{max}	K_L	R^2	q_{max}	n	R^2
50	54.3	0.077	0.995	5.03	2.013	0.947

Table (4): R_L values based on the Langmuir equation

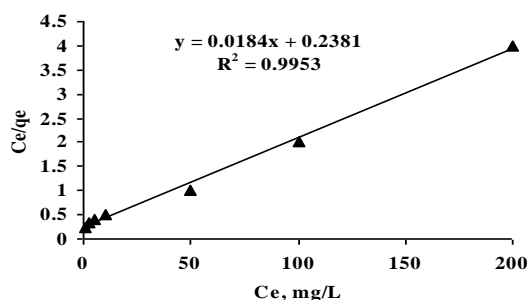| U (VI), mg/L	R_L
10	0.58
20	0.41
30	0.32
50	0.22
100	0.12
150	0.08
200	0.06
300	0.04

y = 0.0184x + 0.2381
$R^2 = 0.9953$

Figure (8): Langmuir adsorption isotherm model of U (VI) on Ambersep 920U Cl.
(Extraction conditions: pH: 2, V: 50 ml, W: 0.1 g resin, T: 25ºC, contact time: 90 min.)
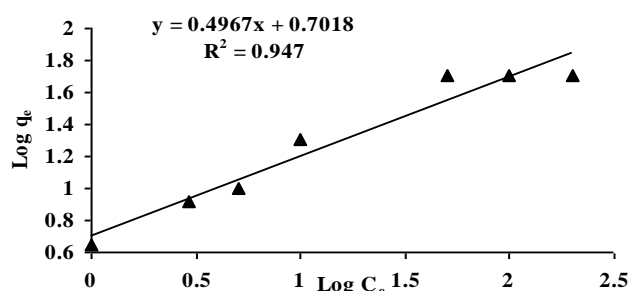
y = 0.4967x + 0.7018
$R^2 = 0.947$

Figure (9): Freundlich adsorption isotherm model of U (VI) on Ambersep 920U Cl.
(Extraction conditions: pH: 2, V: 50 ml, W: 0.1 g resin, T: 25ºC, contact time: 90 min.)

Thermodynamic characteristics:

The thermodynamic parameters of the studied adsorption process have been determined from a series of experiments carried out at various temperatures ranging from 25 to 60 ºC. These parameters were calculated for this system using the following Van˙t Hoff equation:

$$\log K_d = \frac{\Delta S}{2.303R} - \frac{\Delta H}{2.303RT}$$

where K_d (ml/g), ΔH (KJ/mol), ΔS (KJ/mol.K), T (Kelvin) and R (J.K^{-1}.mol^{-1}) are the distribution coefficient, the enthalpy, the entropy, the temperature in Kelvin and the molar gas constant respectively. The plot of Log K_d against 1/T for uranium (VI) adsorption upon Ambersep 920U Cl is shown in Fig. (10). The values of ΔH and ΔS were obtained from the slope and intercept of the latter plot while the Gibbs free energy, ΔG (KJ/mol), is calculated from the following equation [31]:

$$\Delta G = \Delta H - T \Delta S$$

The calculated values of the thermodynamic parameters for U (VI) adsorption on Ambersep 920U Cl are given in Table (5). It was found that the negative value of ΔH shows that U (VI) adsorption is of an exothermic nature whereas the negative numerical values of ΔG which increase with increasing temperature indicating that the adsorption reaction is spontaneous. In addition, the negative ΔS parameter suggests decreasing the system randomness at the solid-liquid interface during the adsorption process.

Table (5): Thermodynamic parameters of uranium (VI) adsorption on Ambersep 920U Cl.

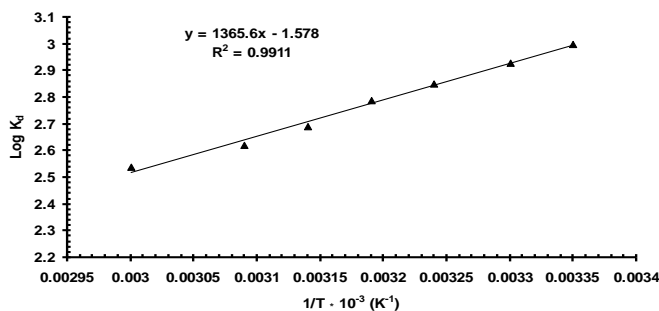| Resin	ΔH	ΔS	ΔG (KJ/mol)						
	KJ/mol	KJ/mol.K	298°K	303°K	308°K	313°K	318°K	323°K	333°K
Ambersep 920U Cl	-26.14	-0.03	-17.2	-17.05	-16.9	-16.75	-16.6	-16.45	-16.15

Figure (11): Effect of temperature on the thermodynamic behavior of uranium (VI) adsorption upon Ambersep 920U Cl.
(Extraction conditions: pH: 2, V: 50 ml, C∘:150 mg/L, W: 0.1g, contact time: 90 min.)

Uranium desorption characteristics:

The desorption or the elution characteristics of uranium (VI) from the loaded Ambersep 920U Cl without removing the retained matrix components has been studied in the present work by several acid, alkali and salt solutions. Thus, various eluting agents including the acids (HCl, H_2SO_4 and HNO_3), the alkalis (Na_2CO_3 and $NaHCO_3$), and the salts (NaCl, Na_2SO_4 and NH_4NO_3) in concentrations ranging from 0.2 to 3 M have been applied. In these experiments, the other parameters were kept constant involving a 5 ml volume of the eluant solution for 1 hour contact time at ambient temperature for o.1 g uranium (VI)-loaded resin. From the obtained results plotted in Fig. (12), it was observed that the elution efficiencies of uranium (VI) ions have increased with increasing the concentration of the applied acids until reaching the maximum values of 84, 99.9 and 66 % for 0.8 M HCl, 1 M H_2SO_4 and 0.6 M HNO_3 respectively and above which the elution efficiencies have gradually decreased. In case of alkalis, the uranium (VI) elution efficiencies have increased with increasing their concentration until reaching the maximum values of 99.9 and 94 % at 0.6 M of either Na_2CO_3 or $NaHCO_3$ respectively. Finally, the uranium (VI) elution efficiencies using the indicated salts have increased with increasing their concentration to obtain 72, 58 and 92 % at 1 M NaCl, 0.6 M Na_2SO_4 and 1 M NH_4NO_3 respectively. Hence, it can be concluded that 1 M H_2SO_4 or 0.6 M Na_2CO_3 can be used for almost quantitative desorption of uranium (VI) from the working Ambersep 920U Cl anion exchange resin.
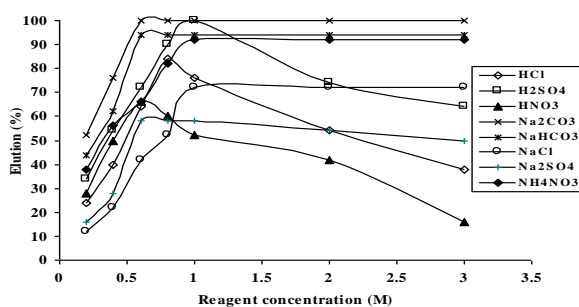

Figure (12): Effect of concentration of the different chemical reagents on uranium elution efficiency.
(Elution conditions: V: 5 ml, T: 25° C, W: 0.1 g resin, contact time: 1 h)

IV.   Conclusion

The strong base Ambersep 920U Cl anion exchange resin developed for high saline solution was applied for uranium (VI) adsorption from a synthetic sulfate solution. The purpose was to determine both the optimum adsorption conditions and the equilibrium and kinetic characteristics. The obtained results indicate that uranium (VI) adsorption is strongly dependent on the pH of the aqueous solution and where under the optimum conditions a maximum adsorption of 50 mg/g resin was obtained at pH 2 for 90 min. shaking time of 0.1 g resin in 50 ml of the synthetic solution assaying 150 mg/L uranium at room temperature. Referring to the theoretical

capacity of the working resin of 1 eq/1 L resin, it can be indicated that this would correspond to 59.5 g U/L resin as the adsorbed uranium (VI) species to the tetravalent trisulfate species. In otherwords, it has been possible to achieve up to about 70 % of the theoretical capacity under the determined optimum conditions. The achieved capacity has actually been found to be in agreement with the Langmuir isotherm and where the adsorption kinetic was found to obey the pseudo second order reaction. Concerning the effect of Cl⁻ concentration, it was found that up to a 30 g/L did not affect the adsorption capacity. Finally, the adsorbed uranium was found to be almost completely eluted by either 1 M H_2SO_4 or 0.6 M Na_2CO_3 solution.

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