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RESEARCH ARTICLE

RECOVERY OF URANIUM FROM SULFATE LEACH LIQUOR USING ETHANOLIC EXTRACTANT OF AERIAL PART OF *HELIANTHUS ANNUUS* PLANT.

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Abstract

The possibility of using *Helianthus annuus* extractant (sun flower) as a solvent extractant for uranium from its sulfate liquor as means for their recovery has been studied. Several experiments were conducted to determine the relevant factors affecting both the extraction and stripping of the uranium from a synthetic solution. Under the optimum conditions, the achieved uranium capacity has attained about 22 mg/g for the ethanolic extractant. The optimum stripping conditions for uranium content from the loaded ethanolic extractant which is rich of some active compound to form complex with uranium included stripping agent type 1M NaCl /1M HCl, aqueous to organic phase ratio (A/O) 1:3, stripping time 15 min and at room temp. From the prepared sulfate leach liquor of of Abu Zeneima ore material (South Eastern Sainai, Egypt) uranium has then been recovered using the working ethanolic extractant under the previously studied optimum conditions, with an efficiency of 98% The obtained strip liquor was then subjected to precipitation using NH_4OH solution at pH of 7.5 and analysis of the obtained precipitate ammonium uranium oxide hydrate [$UO_3NH_3H_2O$] was found assay 76% uranium which has been confirmed using XRD and EDAX analysis.

Introduction:-

Twenty one century, high lights are focused now upon the environmental concerns. One of the important concerns is the useful employment and recycling of the plant and animal remains, on their burning, cotton stalk, rice husk, sun flower stalk and plant cellulosic remains….etc. are essential pollutants to the atmosphere. Thus, the possibility of using the sunflower as extractants for the recovery of lanthanide could be considered as one of improvement of the using of waste management.

Perennial sunflower species are not as popular for gardens due to their tendency to spread rapidly and become invasive. (**Subashini and Rakshitha 2012)** evaluated the methanolic extract seeds of Helianthus annuus L. for the phytochemical present in the plant and results shown that, the carbohydrates, flavanoids, tannins, alkaloids, sapanins, phytosterols, steroids and fixed oils were present in the extract. **(Macias et al. 2008)**.

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In nature, uranium can be found in the Earth's crust at an average concentration of about 2.5 mg/kg but anthropogenic activities, such as utilization of depleted uranium in munitions and nuclear accidents, introduce uranium to the environment on a larger scale. Uranium resulting from mining, reprocessing and disposal activities related to the nuclear industry is a problematic environmental pollutant. The monitoring of the movement of uranium from soil to plants especially to edible plant parts is very important due to possible contamination of the food chain. Uranium presents an exposure hazard due to its chemical toxicity as well as the radioactivity resulting from its decay and its decay products. In plants, uranium is stored mainly in roots, which was demonstrated on hydroponically cultivated sunflower **(Dushenkov et al., 1997). Dushenkov et al., (1997)** reported that sunflower plants were found to have a high affinity for uranium extraction and were selected for treatment of contaminated water.

Blanco et al. (2006), tested the linearity assumption of the validation of soil-to-plant transfer factors of uranium and Ra226 using Helianthus annuls L. grown in a hydroponic medium in addition, transfer of the studied species in both the aerial parts of plants and in the overall seedlings. The results show that the linearity assumption can be considered valid in the hydroponic growth of sunflowers for the radionuclides studied. The ability of sunflowers to translocate uranium and Ra226 was also investigated. In this sense, the removal percentages obtained for uranium and Ra226 were 24% and 42%, respectively. Practically all the uranium is accumulated in the roots. However, 86% of the Ra226 activity concentration in roots was translocated to the aerial part. **Shahandeh and Hossner (2002)**, investigated uranium accumulation from uranium contaminated soil among sunflower plant species. They found also that, uranium accumulated mainly in the roots of plant species.

Generally uranium is influenced by its speciation and low pH conditions **(Lauria et al., 2004).** Uranium is present as a positively charged uranyl ion $UO_2$2+ in low pH samples and is very mobile U accumulation and distribution in plants has been reported by several authors **(Straczek et al., 2010; Véra-Tome et al., 2008, 2009, Ebbs et al., 1998).** Sunflower heavily accumulates U in its roots where it is stored **(Straczek et al., 2010; Véra-Tome et al., 2008).** Conversely, wheat shows low U transfer factors in roots and shoots **(Shahandeh and Hossner, 2002).** This differential response with respect to plant species is explained by their cation exchange capacity **(Dufey et al., 2001; Straczek et al., 2010).**

The present work aims to study using the sun flower hexane extractant from its waste by mixing synthetic solution of uranium for its recovery. The obtained optimum conditions were applied upon real sulfate leach liquor of gibbsite ore materials as a case study.

Materials and Methods:-

Materials;-

Plant materials:-

The aerial part of Helianthus annuus were collected on April (2013) and identified by Botany department, Faculty of Science, Zagazig University.

Extraction of the ethanolic extractant (HAE2):-

The aerial part are dried in the shadow in air draft were comminuted to powder (2 kg) and exhaustively extracted under reflux over a boiling water bath with 5 liters of ethanol(80%) for 3 hours. The extract was filtered; the process was repeated 3 times. The solvent was removed under reduced pressure at about 60 °C. The process yielded finally 150 g of a sticky dark brown material.

Synthetic solutions of REEs have been prepared from their proper salts. REEs solutions were thus prepared by dissolving analytical grade metal salts in distilled water to obtain accurate concentration 200 ppm (mg/L) solution. The pH of this solution was measured and adjusted at 0.1 using sulfuric acid and all the adsorption experiments were run at room temperature.

Experimental procedures:-

Preparation of standard U (VI) and interferences solutions:-

A synthetic uranium solution assaying 200 ppm has been prepared by dissolving the required weight of the uranyl acetate salt in distilled water that slightly acidified with sulfuric acid solution. The solution pH was adjusted at 4 using sulfuric acid solution. On the other hand, for studying the possible metals interference that might be associated

with uranium in its solutions, proper weights of some of their compounds have been dissolved in the prepared synthetic uranium.

Uranium extraction procedure from sulfate solution by HAE2:-

Uranium extraction from either the synthetic solution or that of Abu-Zeneima leach liquor solutions by the ethanolic extractant has been undertaken after its dilution/kerosene to 10 vol % were carried out by shaking the two phases in separating funnels. The aqueous phase was analyzed for its uranium content and that in the organic phase was calculated by the difference. Several series of experiments were carried out to study the effects of the diluent type, HAE2 concentration, pH, the shaking time, the extraction temp., the interfering metal ions and the O/A phase ratio. On the other hand, the practical saturation capacity of the HAE2 for uranium has also been determined by using the multiple contact technique.

Uranium stripping procedure from the loaded HAE2:-

A number of mineral acids, alkalis and NaCl solutions have been used for studying the uranium stripping efficiency from uranium loaded upon the HAE2. For choosing the eluent, both the shaking time and temperature together with O/A phase ratio have been studied .The resultant strip solution is treated in subsequent circuit to produce a metal concentrate while the stripped solvent is returned for cycle to extraction circuit.

Analytical procedures:-

Ethanolic extractant characterization:-

As mentioned above, HAE2 was analyzed for its acid content in the quality control laboratory of Hashem Brothers for Essential & Aromatic Products using the Gas Chromatography Mass Spectrometry (GC-MS) HP 6890 Series A (Agilent). On the other hand, an infra-red analysis has been achieved for the ethanolic extractant using (FTIR) model Thermo Scientific Nicolet IS10, Germany.

Control Analysis for Uranium:-

Control analysis of uranium in the different aqueous stream solutions as well as in the product has been undertaken by the oxidimetric titration after its reduction using a standard solution of ammonium metavanadate **(Mathew, 2009).**

Results and Discussion:-

Characteristics of the ethanolic extractant:-

I.R spectrum of the ethanolic extractant:-

From the achieved IR spectral analysis of the the ethanolic extractant shown in Table (1) and plotted in Fig.(1) before complexation with REEs it is clearly evident that a number of characteristics peaks have been obtained.

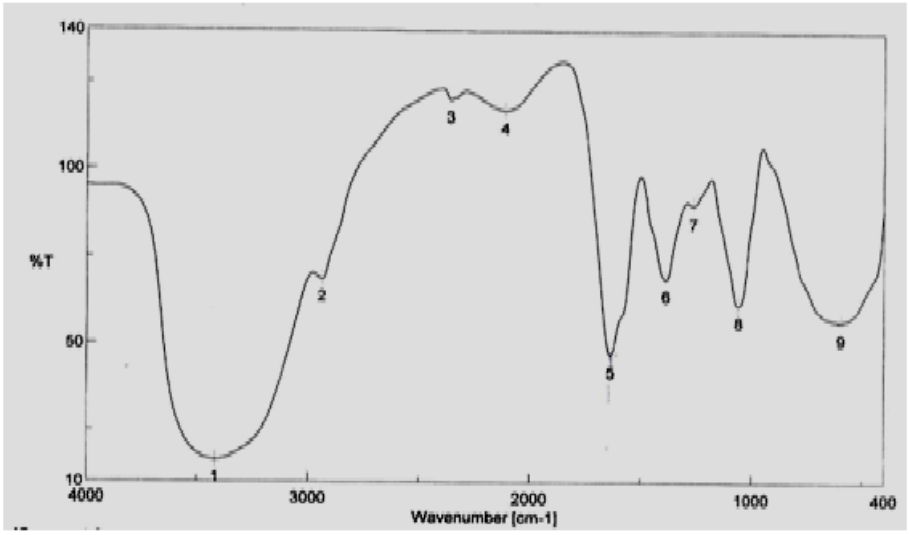


Fig. 1:- IR characteristic spectrum of the ethanolic extractant.

Table 1:- IR spectral analysis of the ethanolic extractant

Peak No	Spectra Value (cm^{-1})	Functional Group
1	3400	OH alcohol
2	2890	C-H
3	2350	X=C=Y (C,O,N,S)
4	2100	C=C
5	1750	C=O
6	1390	C-C
7	1250	C-N
8	1050	C-O

Chromatographic Analysis:-

The almost separated organic compounds were analyzed on Gas Chromatography Mass Spectrometry (GC-MSD).Retention time indices for all compounds were determined while, identification of the components was based on comparison of their mass spectra with those of internal (computer) library W9N11.L (Minimum Quality: 50) and NIST11.L (Minimum Quality: 50) libraries and some reference compounds.As shown in Fig.(2)the major components are 55%benzyl acetate , 16% Linalool and 9%Sotalol (Methane sulphonamide benzene methanol)

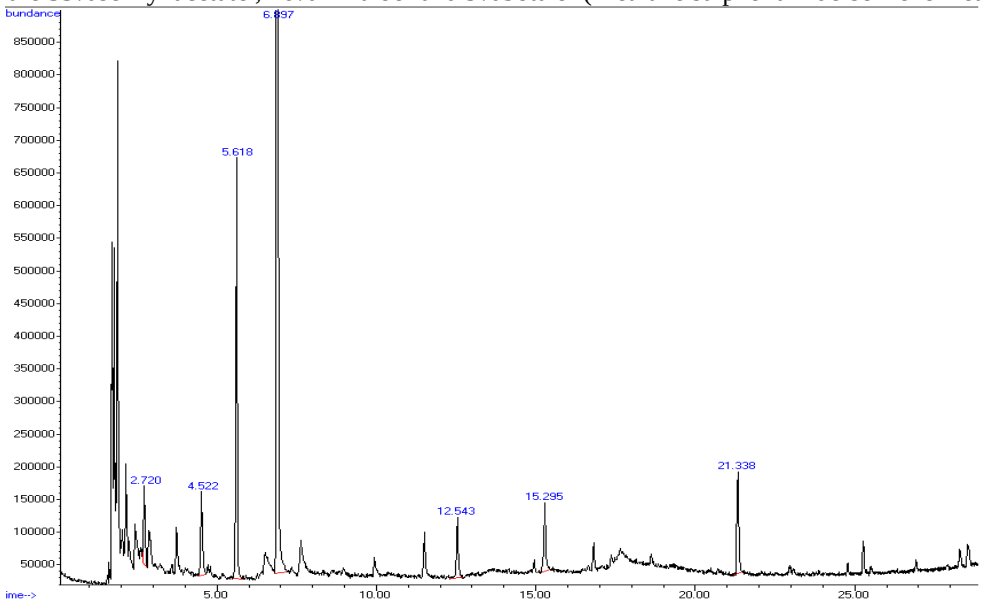


Fig. 2:- Gas chromatography-mass Spectrometry (GC-MS) of the ethanolic extractant.

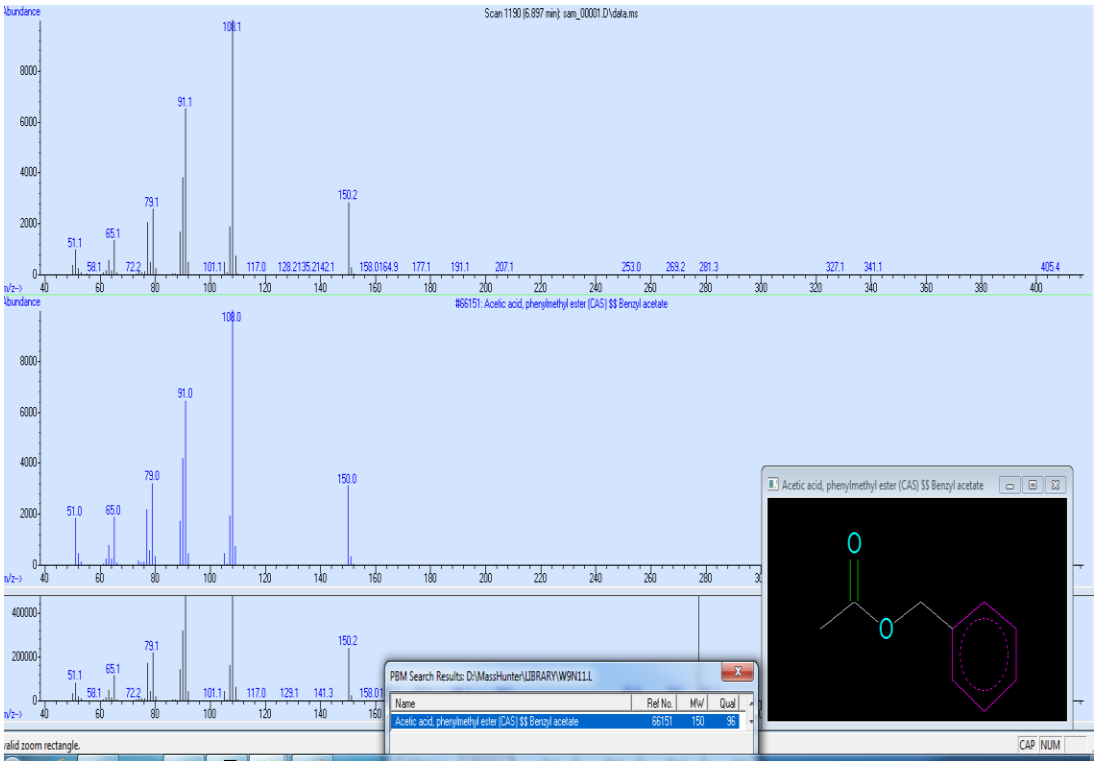


Fig 3:- Chemical structure of benzyl acetate.

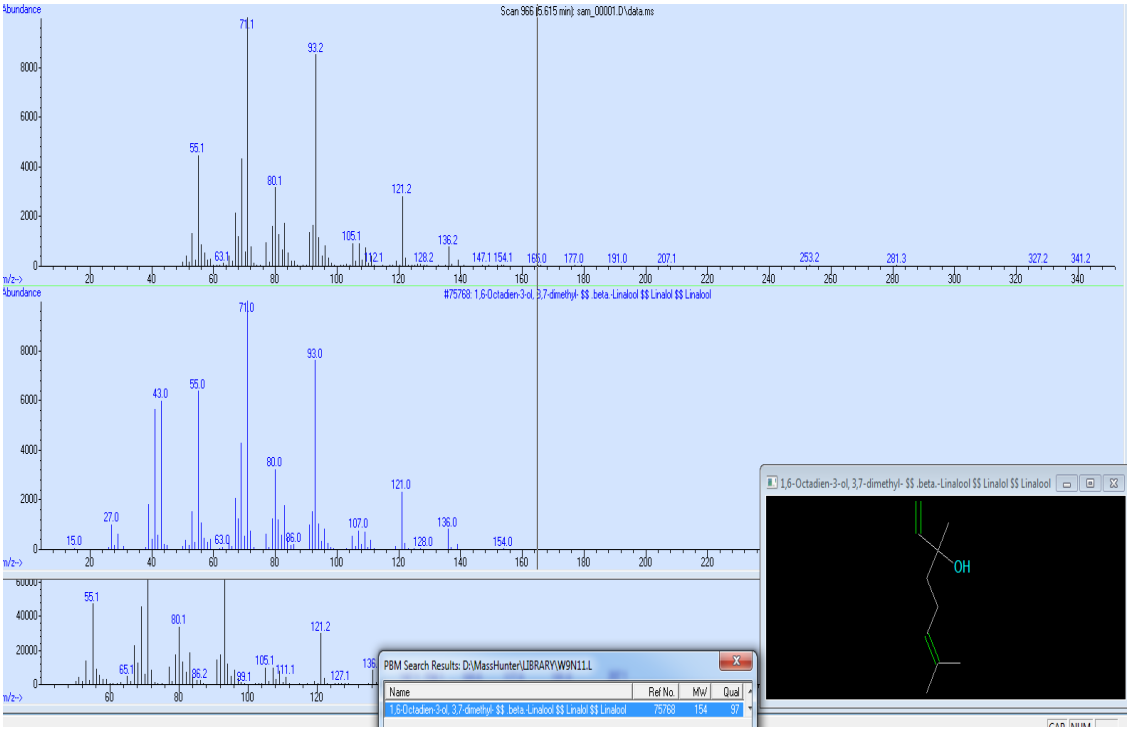


Fig 4:- Chemical structure of Linalool.

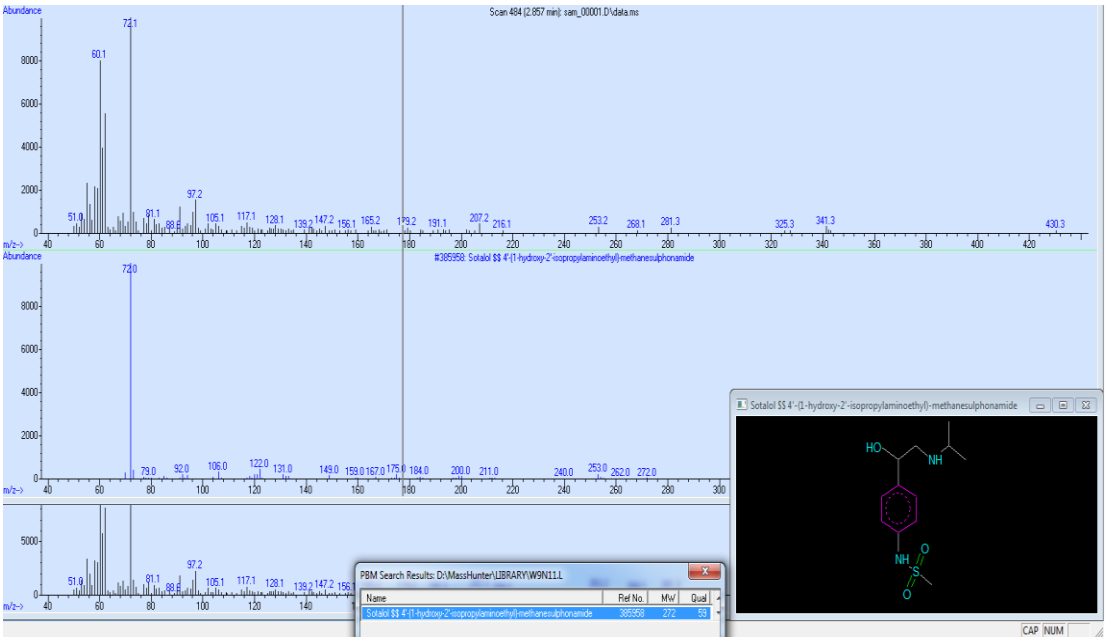


Fig 5:- Chemical structure of Sotalol.

Optimization of the uranium extraction:-

Effect of diluent type:-

To study the effect of the diluent type on uranium extraction from the prepared synthetic solution assaying 200 ppm of uranium three different organic diluents have been used namely; benzene, kerosene and carbon tetra chloride. The extraction process was performed under fixed conditions of a pH 4, a shaking time of 10 min. in an A/O ratio of 1:1 at room temperature and using 10 vol. % HAE. The obtained results indicate that kerosene is the best diluent in which 95% for uranium extraction has been achieved while the toluene and benzene diluents only 50% and 40% for uranium extraction were achieved respectively. Thus carbon tetra chloride was chosen as the best diluent in all extraction experiment**.**

Effect of pH:-

The effect of pH upon uranium extraction was investigated. For this purpose, a series of experiments were performed at different pH values of synthetic solution ranging from 1 to 5 at fixed condition of O/A 1:1, using 10% vol. HAE2 for 10 min. as contact time. From the resulted in **Fig. (6),** it is clear that, the maximum uranium extraction efficiency 98% was achieved at pH 4. Rising the solution pH over 4, leads to decreasing uranium extraction efficiency.

Effect of solvent concentration:-

The effect of the HAE2 concentration on uranium extraction efficiency by contacting equal volumes of synthetic solution and solvents with concentration ranging from 2 to 20% at fixed condition. From the obtained data on Fig (7), the results indicated that, by increasing the concentration of the HAE2 from 2 to 8, the uranium extraction efficiency increased from 45 to 90 % while at 10% a 98% of uranium extraction has been achieved.

Effect of the O/A phase ration:-

To study the effect of the A/O ratio upon uranium by using HAE2, the same conditions were applied. The obtained result revealed an extraction efficiency of uranium attaining 90 and 96% respectively at the A/O ratios of 2/1 and 3/1, in a manner to indicate that 1ml of the HAE2 can adsorb about 3.6 and 5.7 mg U respectively.

Effect of contact time:-

To study the effect of contact time upon uranium extraction efficiency by the HAE2 a set of experiments have been performed at different contact times 1,2,3,5 and 10min. at fixed conditions of O/A 1/1, pH 4 and using 10vol of the

HAE2. The obtained results illustrated at **Fig.(8)** have indicated that uranium extraction is rapidly achieved where at 5 min., up to 95% have been obtained and 99% at 10 min. thus the latter considered as the optimum shaking time.

Effect of temperature:-

Using the previously optimum conditions of pH 4, O/A ratio of 1/1, a shaking time of 10 min. and 10 vol. % HAE2 for the studied system and diluted in carbon tetra chloride, a series of experiments was made to study the effect of temperature in the range from 25 to 70 ºC. As shown in **Fig. (9)**, it was found that by progressively increasing the temperature an adverse effect upon the uranium extraction efficiency from 98 down to 40% has been obtained. This is most probably due to the decomposition of the components of the organic solvent under high temp.

Effect of interfering metal ions upon uranium extraction:-

In order to investigate the possible and extent the interference of some metals ions- that might be associated with uranium in their ores, solution of Cu, Ni, Fe, Zr, V, Ba, and La, Ce, and Y as REEs have been prepared (1000 ppm) concentration for each. To study the effect of latter, 10 ml of the mentioned 9 metal solutions together with 10 ml of a uranium solution assaying also 1000 ppm have been mixed in a manner that each of which would assay 100 ppm. The concerned experiments was then performed under different pH values varying from 1 to 4 at the previously determined optimum conditions .All the obtained results are summarized in **Table (2)** for the studied metal values at the different pH values.

Table 2:- Effect of pH upon the extraction percent of uranium with some interfering metal ions.

pH	**Extraction %**									
	U	Y	Ce	La	V	Fe	Zr	Ba	Ni	Cu
1	2.5	2	5	3	17	12	15	14	18	44
2	4	1	2	2	15	9	12	9	14	32
3	5	3	6	2	10	7	8	7	8	21
3.5	18	3	3	3	8	4	5	4	6	11
4	96	2	1	3	1	20	1	2	3	3
4.5	60	1	1	2	1	2	1	2	3	3

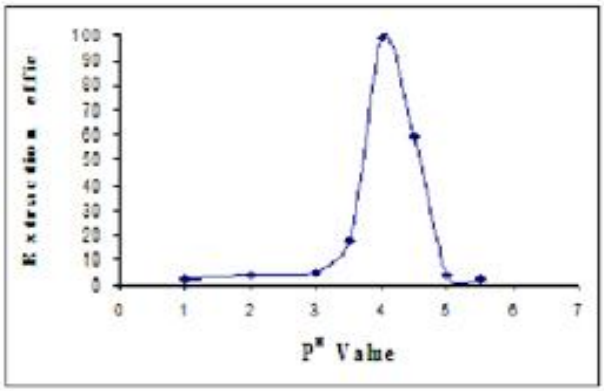


Fig.(6): Effect of pH upon uranium extraction efficiency % by HAE

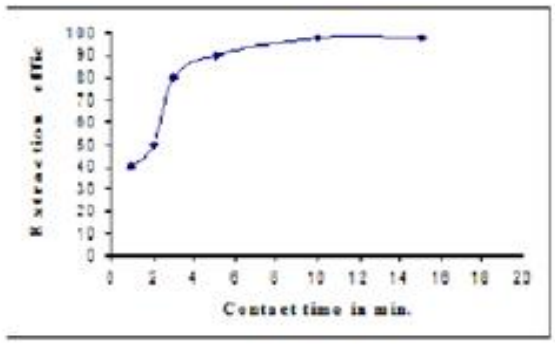


Fig.(8) : Effect of contact time upon uranium extraction efficiency % by HAE.

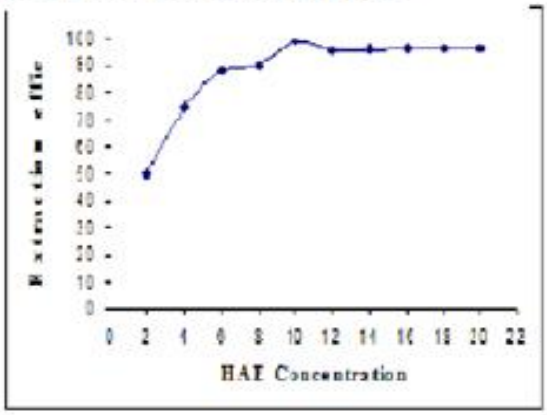


Fig.(7): Effect of HAE Concentration upon uranium extraction efficiency, %.

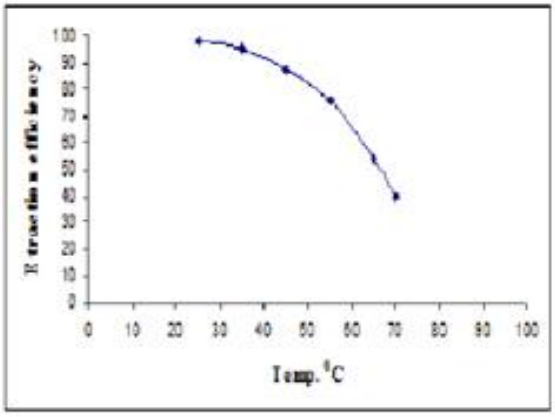


Fig.(9): Effect of temperature upon extraction efficiency % by HAE.

From the above studied of uranium extraction factors, it can be concluded that the optimum extraction conditions for about 98% of uranium content from sulfate solution via HAE2 would be summarized as:

A/O	:	1:1
Contact time	:	10 min.
Ethanolic extractant Concentration	:	10 %
Temperature	:	room temp.
pH	:	4

Uranium saturation capacity:-

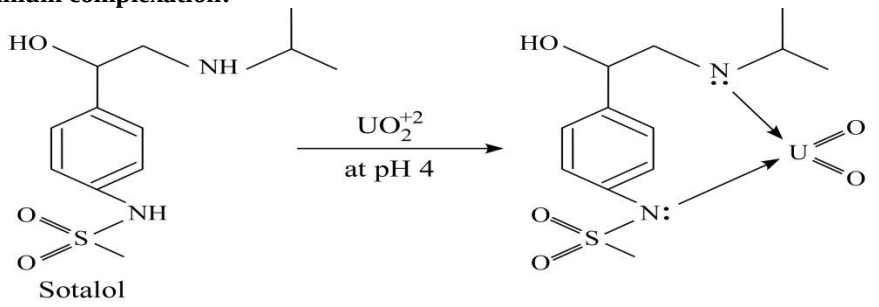
To determine the saturation capacity of the HAE2 an known volume of the extractant has repeatedly been contacted with the prepared synthetic uranium solution under the previously determined optimum conditions using 1g of the HAE2 (10 vol.% in carbon tetra chloride). After each contact, uranium was analyzed in the obtained raffinate till almost saturation of the extractant. From the results shown in Table (3), it is clearly evident that the saturation capacity of the HAE2 attains about 22mg /1g of extractant for uranium. The obtained data support indeed the possible mechanism of uranium species extraction by the HAE2.

Table 3:- Uranium saturation capacity by the HAE2

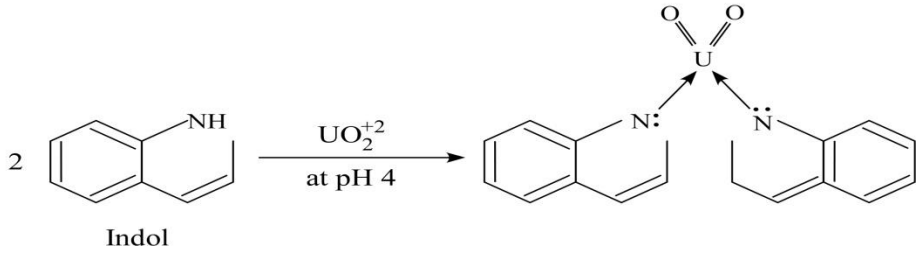
Contact number	Uranium distribution	
	Assay in raffinate , ppm	Loaded amount mg/1g HAE2
1	Nil	6
2	Nil	6
3	200	4
4	300	3
5	450	1.5
6	500	1
7	450	0.5
8	600	Nil
Total		22

Mechanism of uranium complexation:-

i)



ii)



Physical parameters:-

Thermodynamic characteristics of uranium extraction:-

Variations of uranium extraction data with temperature for uranium extraction from the aqueous phase by used HAE2 in kerosene was used to calculate the thermodynamic constants including the standard enthalpy (ΔH), and the standard entropy (ΔS) based on Van't Hoff plot using the following formula:

$$\ln K_d = \frac{\Delta S^\circ}{R} - \frac{\Delta H^\circ}{RT}$$

Where K is the equilibrium constant R = 8.3145 J mol-1K-1 and T = absolute temperature in Kelvin. ΔH and ΔS were determined from the slope and intercept of ln Kd versus 1/T graph. **Fig. (10)** Plots ln Kd versus 1/T, K-1 (in case of HAE) which give a straight line whose slope equals (-ΔH / R) for the extraction of uranium. The ΔH and ΔS values for uranium, in case of HAE2, were – 91.26 kJ/mol and -272 J/mol k respectively as calculated from the slope and intercept using the Van't Hoff equation. These values of ΔH and ΔS have then been used to obtain the corresponding free energy (ΔG= − 10.2 kJ/mol) at 298°K for HAE using the following equation:

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

The negative value of ΔH indicates that the extraction of uranium in this system is an exothermic process and that the reaction becomes more favorable at room temperature. The negative value of ΔG indicates that the reaction is

spontaneous. On the other hand, the observed decrease in the negative values of ΔG with elevated temperature implies that the reaction becomes more favorable at room temperatures.

Kinetic characteristics of uranium extraction by HAE:-

In terms of kinetic modeling, the pseudo-first-order and pseudo-second-order equations were used for the mathematical interpretation of the uranium extraction rate from the aqueous phase by HAE2. The pseudo-first-order equation is represented as follows:

$$\log(q_e - q_t) = \log q_e - \frac{k_1 t}{2.303}$$

Where qe and qt are the amounts of metal ions adsorbed at equilibrium and at time t respectively, and k1 is the equilibrium rate constant of the pseudo first-order equation (1/min). On the other hand, the pseudo-second-order kinetic model is represented as follows:

$$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{t}{q_e}$$

Where k_2 is the equilibrium rate constant of pseudo second-order equation. The slope and intercept of the plot t/qt versus t were thus used to calculate the pseudo second-order rate constants k_2 and qe. The pseudo-first -order kinetic model was found to best fit the experimental results of uranium extraction by HAE in kerosene with correlation coefficients very close to unity other than pseudo second-order kinetic model **(Figs. 11 and 12)** and the result agree with that reported by (**Mckay et al., 1988**).

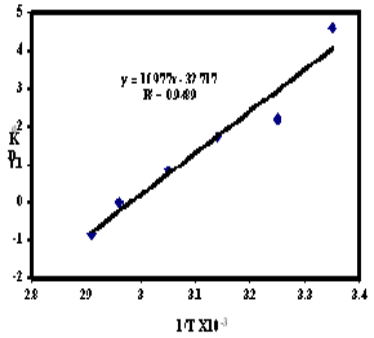


Fig. (10): Plot of $\ln K_d$ against reciprocal temperature for uranium from the 200 ppm by HAE2

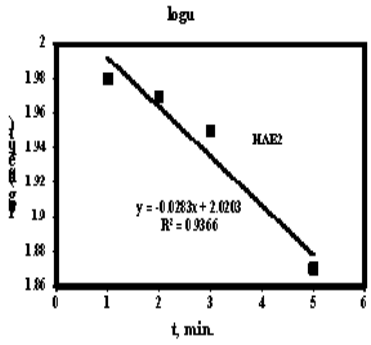


Fig. (11): Plot of log (q_e- q_t) versus time (t) for kinetic extraction of uranium from the 200 ppm aqueous solution by HAE2 at 25°C

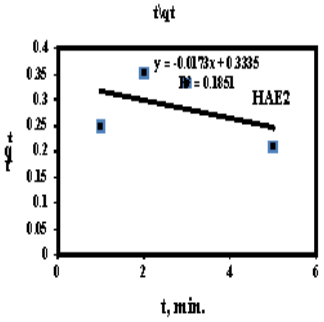


Fig. (12): Plot of t/q_t versus time (t) for kinetic extraction of uranium from the 200 ppm aqueous solution by used HAE2 at 25°C

Table 4:- Pseudo First-order constants of uranium extraction by used ethanolic extractant at 25ºC.

Pseudo First-order constants	Result of HAE2
K_1	0.065
q_e	104.71
R^2	0.94

Optimization of the uranium stripping factors loaded upon the ethanolic extractant:-
Uranium stripping was carried out at room temperature by shaking equal volumes of the loaded solvent with a suitable stripping solution for a proper time. Factors influencing the stripping efficiency include stripping agent type and its concentration, aqueous to organic phase ratio (A/O), stripping time and temperature.

Effect of the stripping agent type:-
Different stripping agents were applied to strip uranium from the loaded 10% the HAE/kerosene. These included distilled water and 1 M of mineral acids HCl, H_2SO_4 and HNO_3 as well as NaCl/mineral acids (HCl, H_2SO_4 or HNO_3) mixtures. The stripping experiments were carried out in an A/O ratio of 1/1 for 10 min. contact time at room temp. The obtained results presented in **Table (5)** reveal that NaCl acidified H_2SO_4 at the mentioned molarity is actually the most efficient stripping agent for uranium from the loaded with 95% efficiency.

Table 5:- Effect of stripping agent type on uranium stripping efficiency loaded upon HAE2

Stripping agent type/ conc.,	U stripping efficiency, %
Water	20
HNO_3 (1mole)	65
HCl (1mole)	67
H_2SO_4 (1mole)	86
HNO_3/NaCl (mole / mole)	75
NaCl /HCl (mole / mole)	90
NaCl/ H_2SO_4 (mole / mole)	95

It is interesting to mention here, that the uranium will stripped with NaCl/H_2SO_4 solution (mole/mole).

Effect of molarity NaCl/H_2SO_4 upon uranium stripping efficiency from the loaded solvent:-
The effect of NaCl and H_2SO_4 molarity ratio on uranium stripping from the loaded 10% HAE2 was studied while keeping the other stripping factors of contact time for 10 min., the settling time for 5 min. in an A/O phase ratio of 1/1. From the obtained results given in **Table (6)**, it is obvious that NaCl/H_2SO_4 ratio equal 1 has resulted 95% uranium stripping efficiency.

Table 6:- Effect of NaCl and H_2SO_4 molarity on uranium stripping from the loaded HAE2

Molarity of NaCl /H_2SO_4 ratio	U stripping efficiency %
H_2SO_4/ NaCl (mole / mole)	95
H_2SO_4/ NaCl (0.5 mole/1 mole)	85
H_2SO_4/ NaCl (0.25 mole/ 1 mole)	70

Effect of O / A phase ratio:-
In a manner to increase the uranium concentration in the stripping aqueous phase the effect of the A/O phase ratio upon the uranium stripping efficiency from the loaded HAE2 was studied up to the ratio of 3/1 using 1M NaCl /1M H_2SO_4. In these experiments, the other stripping factors were fixed at their studied optimum values. From the obtained results, it was shown that upon increasing the O/A ratio from 1/1 to 2/1, about 98% of uranium stripping was achieved while at the ratio of 3/1 give the same result as the A/O ratio of 2/1 thus the A/O of 3/1 is the optimum phase ratio.

Effect of contact time:-
The effect of a lower contact time upon the uranium stripping efficiency by mixed of 1M NaCl/1M H_2SO_4 from the loaded10% HAE was studied for 5, 10 15 and 20 min. using the above mentioned optimum molarity of NaCl / H_2SO_4 at an O/A ratio of 3/1 at room temperature and using a settling time of 5 min. The corresponding uranium

stripping efficiencies indicate that a contact time of 15 min. as stripping time is the sufficient to achieve about 98% of the total uranium as shown in **Table(7).**

Table 7:- Effect of stripping time upon uranium stripping efficiency for the HAE2

Stripping time	Uranium stripping efficiency%
5	66
10	75
15	98
20	98

From the above studied of uranium stripping factors, it can be concluded that the optimum stripping conditions for about 98% of uranium content from the loaded HAE would be summarized as following:

Stripping agent type : 1M NaCl /1M H_2SO_4
A/O : 1:3
Contact time : 15 min.
Temperature : room temp

A Case study:, Abu-Zeneima ore material (South Eastern Sainai, Egypt) as a case study for uranium extraction using HAE2.

According to, the optimum leaching conditions of uranium from its mineralization at Abu-Zeneima ore material (South Eastern Sainai, Egypt) include a H_2SO_4 acid concentration 800 g/L, an agitation time of 4h, a S/L ratio of 1/2 at 100°C and using an ore grain size of – 60 mesh.**(El Hazek , 2008).**

Characterization of Abu-Zeneima gibbsite ore:-

As previously mentioned, the working technological sample was provided from Abu Zeneima gibbsite ore lenses found in the shale beds. Results of the complete chemical analysis of the working sample are shown in Table (8).

Table 8:- Chemical analysis of Abu Zeneima ore material

Major oxide	%	Traces	ppm	REEs individual	
				Element	ppm
SiO_2	21.07	U	560	La	209
TiO_2	0.97	ΣREEs	3000	Ce	834
Al_2O_3	30.43	Zn	3650	Nd	278
Fe_2O_3	8.24	Cr	760	Sm	214
MgO	3.09	V	134	Eu	111
MnO	4.86	Cu	167	Gd	460
Na_2O	2.14	Ni	89	Tb	72
P_2O_5	0.33	Mo	19	Dy	19
CaO	7.25	Cd	45	Ho	0.75
K_2O	1.10			Yb	0.98
L.O.I.*	20.17			Tm	0.67
Total	99.55			Y	500

From the prepared sulfate leach liquor of Abu-Zeneima mineralization uranium have then been recovered using HAE under the previously studied optimum conditions. Accordingly, a uranium extraction efficiency of 98% has been obtained. Subsequently, the uranium-loaded the HAE was subjected to uranium stripping using 1M NaCl /1M H_2SO_4 under the studied optimum stripping factors. These included an A/O ratio of 3/1 at room temperature for 15 min. contact time.

Uranium Precipitation:-

The striping solution containing uranium would then be subjected to pH adjustment by using NH_4OH, which would be added to the solution, with continuous stirring to precipitate uranium at pH 7 as ammonium uranium oxide hydrate $[UO_3NH_3H_2O]$. After filtration, the produced filtrate would be re-acidified in order to be recycled in a new elution process. **Fig. (13)** Shows XRD analysis of the obtained $[UO_3NH_3H_2O]$ product**.**

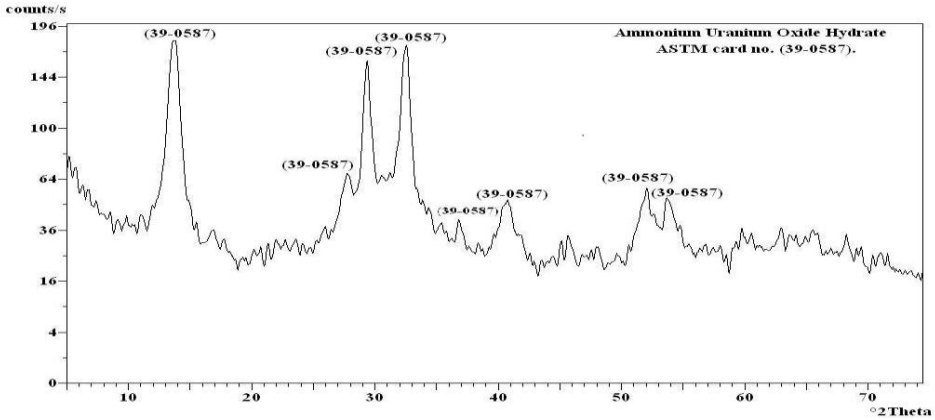


Fig. 13:- XRD analysis of the obtained **[$UO_3NH_3H_2O$]** product.

Conclusion:-

The potentiality of the sunflower as extractant (HAE) for uranium from its sulfate solutions has actually been proven and the studied relevant factors have actually been optimized. These involved a 10 vol. HAE in kerosene, an O/A ratio of 1:1 for a shaking time 10 min. at the pH of 4. Under these conditions, the achieved uranium capacity has attained 33mg/g for uranium. The loaded uranium was afterward completely eluted using NaCl / H_2SO_4 solution Finally, the working HAE was successfully applied for uranium recovery from an actual sulfate leach liquor mineralization in from the actual sulfate leach liquor of Abu Zeneima ore material (South Eastern Sainai, Egypt).

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