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Effect of Triton X-100 on the Spectrophotometric Determination of Aluminium in the Presence of Iron(III) - Application to Various Water Samples

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ABSTRACT

An accurate simple, rapid and direct spectrophotometric method for the determination of aluminium in presence of iron (III) was developed. The method is based on the reaction of aluminium (III) with xylenol orange at pH 4.3 using potassium hydrogen phthalate buffer solution to form a stable orange-red coloured complex which has maximum absorption at 512 nm. This study is showing the effect of triton X-100 on the spectrophotometric determination of aluminium which effected the stability, limits of Beer's law, blanck value and final absorption spectrum. Beer's law was obeyed over the range of (1-200) µg/25 ml (i.e 0.04-8.0 ppm). The molar absorptivity and Sandell's sensitivity of the coloured complex are 1.173×10^{4} $l.mol^{-1}.cm^{-1}$, 0.00230 $\mu g.cm^{-2}$ respectively. The interference caused by iron (III) was suppressed by adding sodium cyanide as masking agent. The method has been applied successfully for determining aluminium (III) in various water samples.

The same work was done for the spectrophotometric determination of aluminium in the absences of triton X-100. While the analytical parameters recorded are 1.045×10^{4} $l.mol^{-1}.cm^{-1}$, 0.00258 $\mu g.cm^{-2}$, the molar absorptivity and Sandell's sensitivity of the coloured complex respectively, and limits of Beer's law are (5-100) µg/25ml (i.e. 0.2-4.0 ppm).

Keywords: Aluminium(III), Xylenol Orange, Triton X-100, Spectrophotometric.

تأثير الـ (Triton X-100) على التقدير الطيفي للألومنيوم بوجود الحديد (III) - التطبيق على نماذج مائية مختلفة

الملخص

تم تطوير طريقة طيفية بسيطة وسريعة ومباشرة لتقدير الألمنيوم بوجود الحديد (III) حيث تعتمد هذه الطريقة على تفاعل الالمنيوم مع الزايلينول البرتقالي بوجود الـ (triton X-100) عند الدالة الحامضية 4.3 باستخدام فثالات البوتاسيوم الهيدروجينية كمحلول منظم لتكوين معقد احمر مستقر يقاس أقصى امتصاص له عند الطول ألموجي 512 نانومتر. أظهرت هذه الدراسة تأثير الـ (triton X-100) على التقدير الطيفي للألمنيوم وتأثيره على استقرارية المعقد المتكون وحدود قاون بير وقيم امتصاص المحلول الصوري والطيف النهائي للمعقد المتكون. كانت حدود قانون بير ضمن المدى (1-200) ميكروغرام/ 25 مل (0.04-8.0) جزء لكل مليون وكانت الامتصاصية المولارية وحساسية ساندال للمعقد الملون هي 1.173×10^{4} لتر.مول$^{-1}$.سم$^{-1}$، 0.00230 مايكروغرام.سم$^{-2}$ على التوالي، وتم إزالة التداخل الناجم عن الحديد (III) بإضافة سيانيد الصوديوم كعامل حجب وتم تطبيق الطريقة بنجاح لتقدير الألمنيوم في نماذج مائية مختلفة.

تم دراسة تأثير غياب الـ (triton X-100) على تقدير الألمنيوم باستخدام الطريقة المقترحة حيث كانت القيم التحليلية للمعقد الملون المتكون هي 1.045×10^{4} لتر.مول$^{-1}$.سم$^{-1}$ و0.00258 مايكروغرام.سم$^{-2}$ لمعامل الامتصاص المولاري ودلاله ساندل للحساسية على التوالي، اما حدود قانون بير فقد كانت (5-100) ميكروغرام/ 25 مل، (0.2-4.0) جزء لكل مليون.

الكلمات الدالة: الالمنيوم، الزايلينول البرتقالي، triton X-100، تقدير مطيافي.

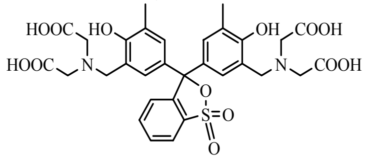
INTRODUCTION

Aluminium is a silvery white member of the boron group of chemical elements. It is not soluble in water under normal circumstances. Aluminium is the third most abundant element in the earth's crust (Meija *et al.*, 2016). Aluminium forms strong chemical bonds with oxygen, compared to most other metals. Structural components made from aluminium and its alloys are vital to the aerospace industry and are important in other areas of transportation and structural materials. The most useful compounds of aluminium, at least on a weight basis, are the oxides and sulfates (Devoret and Schoelkopf, 2013).

Aluminium is remarkably nontoxic, the health effects of aluminium are of interest in view of the widespread occurrence of the element in the environment and in commerce. Human exposure to aluminium. The human population is exposed to aluminium (Al) from diet, antacids and vaccine adjuvants, but frequent application of Al-based salts to the underarm as antiperspirant adds a high additional exposure directly to the local area of the human breast (Exley, 2013). Al has been measured in human breast tissues/fluids at higher levels than in blood, Al can adversely impact on human breast epithelial cell biology (Darbre, 2016). Aluminium's free metal cation, Alaq3+, is highly biologically reactive. Biologically reactive aluminium is present throughout the human body and while, rarely, it can be acutely toxic, much less is understood about chronic aluminium intoxication. Alzheimer's disease is a symptom of chronic aluminium intoxication over decades (Exley, 2016). Aluminum has been shown by independent researchers to be particularly genotoxic to the genetic apparatus, and it has become reasonably clear that aluminum disturbs genetic signaling programs in the CNS that bear a surprising resemblance to those observed in Alzheimer's disease (AD) brain. (Pogue and Lukiw, 2016)

Several Spectrophotometric methods have been used for the determination of aluminium, some of these methods have used different kinds of reagent such as alizarin red S (Eder *et al.*, 2015), Eriochrome Cyanine R (Siriangkhawut *et al.*, 2013), 5-Bromo-2-hydroxy-3-methoxybenzaldehyde-p-hydroxybenzoic hydrazone, (Saritha and Reddy 2014), 2-hydroxynaphthaldehydebenzoylhydrazone (Jamaluddin *et al.*, 2010), 8-hydroxyquinoline (Santarossa *et al.*, 2016), (Panhwar *et al.*, 2018), N-((2-hydroxy-naphthalen-1-yl)methylene) acetylhydrazide (Al-Kindy *et al.*, 2015), Chrome Azurol S (Ni *et al.*, 2007) and (Shishov *et al.*, 2014). A flow injection have been used for the determination of aluminium with Eriochrome cyanine R (Khanhuathon *et al.*, 2015), other method used schiff base (Rana *et al.*, 2017), A flame atomic absorption spectrometry also used for the determination of aluminum with xylidyl blue and Triton X-114 (Ulusoy *et al.*, 2011), and reverse-phase high-performance liquid chromatography using a fluorescence detector have been used for determined of aluminium (Heena *et al.*, 2015), also the elimination of iron interference in the molecular spectrophotometric determination of aluminum (Andrade *et al.*, 2008), other methods using the H-point standard addition method (Kobra *et al.*, 2007), the complexes with xylenol orange (XO) is presented for the rapid determination of aluminium (Carpani *et al.*, 2004).

Xylenol orange also known as 3,3'-Bis [N,N-bis(carboxymethyl)aminomethyl]-o-cresolsulfonephthalein tetra sodium salt is an organic reagent, most commonly used as a tetrasodium salt as an indicator for metal titrations (Marczenko, 2000).



$C_{31}H_{32}N_2O_{13}S$

Mwt. = 672.67 g/mol

The proposed work aims mainly to develop a sensitive spectrophotometric method for the determination of aluminium in various water samples via xylenol orange dye. Also this work study the effect of presence and absence of triton X-100 on the determination of aluminium and eliminated the interference caused by iron(III).

EXPERIMENTAL

Apparatus

The absorption spectra and absorbance measurements were recorded on a double-beam Shimadzu UV-Visible recording spectrophotometer UV-160 with 1.0 cm matched plastic cells. pH measurements were performed using HANNA instrument pH 211 microprocesser pH meter.

Reagents

All chemicals used were of analytical reagent grade.

Stock aluminium (III) solution 100 µg/ml: This solution was prepared by dissolving 0.1391g of hydrated aluminum nitrate $Al(NO_3)_3.9H_2O$ (Fluka) in distilled water and the volume was completed to the mark with distilled water in a 100 ml volumetric flask. Working solution 5 µg/ml solution of aluminum (III) was prepared by appropriate dilution of the stock solution with distilled water.

Triton X-100 solution (1%): This solution was prepared by dissolving 1 g of triton X-100 (Fluka) in distilled water and the volume was completed to the mark in a 100 ml volumetric flask with distilled water.

Xylenol orange solution (1×10^{-3} M): This solution was prepared by dissolving 0.1681 g of chromogenic reagent xylenol orange (Fluka) in distilled water, then complete the volume with distilled water to the mark in a 250 ml volumetric flask. The solution was then transferred to a dark bottle it was stable for at least one week.

Buffer solution (pH 4.3): This solution was prepared by mixing 50 ml of 0.1 M potassium hydrogen phthalate and 4.7 ml of 0.1 M sodium hydroxide and the volume is diluted to the mark, with distilled water, in a 100 ml volumetric flask (Perrin and Dempsey, 1974).

Sodium cyanide solution (0.01M): This solution was prepared by dissolving 0.1225 g of sodium cyanide in distilled water then the pH of the solution was then brought to 4.3, the volume was completed to the mark with distilled water in a 250 ml volumetric flask.

Procedure and calibration graph

Aliquots of standard solution 1-200 µg of aluminium was transferred into a series of 25 ml volumetric flask. To each flask, 3 ml of KH-phthalate buffer solution, 2 ml of triton X-100 (1%) and 2 ml of xylenol orange 1×10^{-3} M were added. The reaction mixture were diluted to the mark with distilled water and mixed well. The absorbance of the produced coloured complex was measured at 512 nm against the corresponding reagent blank. A linear calibration graph (Fig.1) is obtained over the range (i.e 0.04-8.0 ppm) with a molar absorptivity 1.173×10^4 $l.mol^{-1}.cm^{-1}$ and sandell 0.00230 $\mu g.cm^{-2}$ in presence of triton X-100.

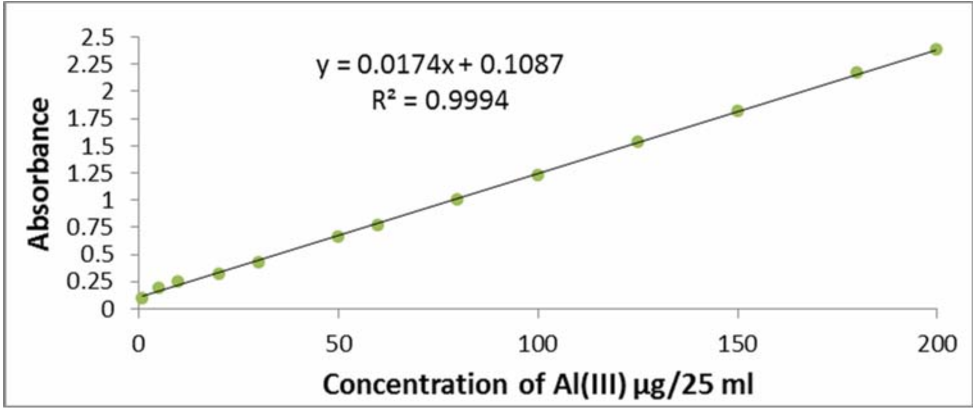


Fig. 1: Calibration graph of aluminium in presence of triton X-100

RESULT AND DISCUSSION

Aluminium is complexed with xylenol orange in presence of triton X-100 at pH 4.3 of potassium hydrogen phthalate buffer solution, which form an intensely-coloured complex that shows an absorption maxima at 512 nm against reagent blank solution. This work explain the effect of triton X-100 on the determination of aluminium.

Study of the optimum experimental conditions

For the following investigations, 5 µg of aluminium is taken in 25 ml volumes.

Effect of pH

The effect of pH on the intensity of coloured complex is studied by adding different amounts (0.1-1.0) ml of 0.001 M from (sulphuric acid, hydrochloric acid, nitric acid, acetic acid) and (0.1-2.0) ml of sodium hydroxide solutions to an aliquot of solution containing 5 µg of aluminium. The intensity of absorption were measured against the reagent blank. The results are shown in (Table 1 and 2) were carried out in case of absence of triton X-100:

Table 1: Effect of different kinds and amounts of acids

Kind of acid (0.001) M	Absorbance/ ml of acid					λ_{max}	Final pH
	0.1	0.3	0.5	0.7	1.0		
Sulphuric acid	0.170	0.153	0.110	0.093	0.046	512	2.80-3.63
Hydrochloric acid	0.144	0.121	0.108	0.087	0.053	511	2.61-3.58
Nitric acid	0.099	0.083	0.065	0.043	0.028	510	2.70-3.52
Acetic acid	0.118	0.094	0.071	0.048	0.039	512	2.57-3.84
Without acid	0.194					512	4.31

Table 2: Effect of 0.001 M sodium hydroxide

ml of NaOH (0.001) M	Absorbance	λ_{max}	Final pH
0.1	0.128	499	4.68
0.3	0.091	496	4.92
0.5	0.088	501	5.16
0.7	0.064	503	5.54
1.0	0.046	499.5	5.21
2.0	0.020	501	6.71
Without base	0.194	512	4.31

The results in (Table 1 and 2) indicated that the addition of acid or base gave no useful effect. Therefore, the use of acid or base was omitted in the subsequent experiments. Several buffers (Purrin and Dempsey, 1974) of pH 4.3 were prepared and their effects on using different amounts were studied. The results were summarized in (Table 3).

Table 3: Effect of buffer solutions

ml of buffer solution	Absorbance */ ml of buffer added				
	Citric acid-NaOH	Tartaric acid- NaOH	KH-phthalate-NaOH	Succinic acid-NaOH	Citric acid-sodium citrate
1	0.112	0.130	0.191	0.143	0.081
2	0.096	0.124	0.199	0.131	0.073
3	0.088	0.110	0.204	0.128	0.066
4	0.073	0.092	0.201	0.119	0.050
5	0.052	0.062	0.195	0.100	0.038
Final pH	3.82-4.61	3.29-4.31	3.87-4.64	3.56-4.43	3.47-4.52

*Measured at λ= 512 nm, Absorbance without buffer solution = 0.193.

The results in (Table 3) indicate that 3 ml of KH-phthalate-NaOH buffer gives maximum absorbance, and enhances the stability of the product hence, it is selected for the subsequent experiments.

Effect of reagent amount

The effect of different amounts of 1×10^{-3} M xylenol orange were added to the different amounts of aluminium (III) in two set of volumetric flasks, while other conditions being kept constant was studied. 1 ml of the reagent solution has been found to be optimum volume without using triton X-100, but 2 ml of the reagent solution has been found to be optimum volume in presence of triton X-100 since the linearity (correlation coefficient) is good, and this amount of the reagent gives lower value of reagent blank as shown in (Table 4).

Table 4: Effect of reagent amount

ml of 1×10^{-3} M xylenol orange solution	Absorbance / µg of Al^{+3} in 25 ml (in the absence of triton X-100)								
	3	**5**	**15**	**30**	**50**	**70**	**100**	**r^2**	**Blank**
0.5	0.051	0.093	0.211	0.366	0.411	0.652	0.633	0.977479257	0.052
1.0	0.101	0.181	0.401	0.691	0.964	1.279	1.548	0.999391782	0.089
1.5	0.097	0.165	0.291	0.573	0.812	1.188	1.402	0.997091837	0.103
Absorbance / µg of Al^{+3} in 25 ml (in the presence of 2 ml of 1% triton X-100)									
	3	5	25	50	100	150	200	r^2	Blank
1.5	0.073	0.183	0.322	0.603	1.377	1.244	1.883	0.966944147	0.044
2.0	0.099	0.211	0.372	0.831	1.311	1.912	2.438	0.999314577	0.057
2.5	0.104	0.174	0.392	0.821	1.293	1.934	2.178	0.993353935	0.094

Effect of masking agent:

The effect of different amounts 0-5 ml of 0.01 M of various masking agents such as (EDTA, NaF, NTA, EGTA, CDTA) adjusted to pH 4.3 on absorbance was studied. The results are shown in (Table 5).

Table 5: Effect of masking agents

Masking agent	Absorbance / ml of masking agent added						
	0.0	**1.0**	**2.0**	**3.0**	**4.0**	**5.0**	**λ_{max}**
EDTA*	0.211	0.077	0.041	0.011	0.008	0.002	511
NaF		0.092	0.073	0.052	0.032	0.012	500
NTA**		0.111	0.101	0.092	0.072	0.055	512
EGTA***		0.133	0.092	0.052	0.032	0.022	510
CDTA****		0.123	0. 117	0.097	0.058	0.040	509

*EDTA= Ethylendiamintetraacetic acid.

** NTA= Nitrilotriacetic acid.

***EGTA=Ethylenglycol-O,O-bis(2-aminoethyl)-N,N,N,N-tetraaceticacid.

****CDTA=Trans-1,2-diaminocyclohexane-N,N,N,N-tetraacetic acid monohydrate.

The results shown in (Table 5) indicate that the addition of masking agents solution give no useful results therefore it was ommited for the subsequent experiments.

Effect of surfactants

The presence of surfactants in a coloured complex solution was tested such as sodium dodecyl sulphate (SDS) (anionic surfactant), cetyltrimethylammonium bromide (CTAB), cetylpyridinium chloride(CPC) (cationic surfactants) and triton X-100(non-ionic surfactant). The results in (Table 6) indicate that the addition of surfactants give no useful effect on absorbance except triton X-100. Therefore, the amount of triton X-100 was studied as shown in Fig. (2).

Table 6: Effect of surfactant

Surfactant	Absorbance / ml of surfactant added				
	1.0	2.0	3.0	4.0	5.0
Cetyltrimethylammonium bromide	0.178	0.128	0.121	0.082	0.006
Sodium dodecylsulphate	0.189	0.112	0.053	0.022	0.007
Cetyl pyredinium chloride	0.178	0.133	0.111	0.092	0.006
Triton X-100	0.194	0.219	0.214	0.217	0.215
Without surfactant	0.210				

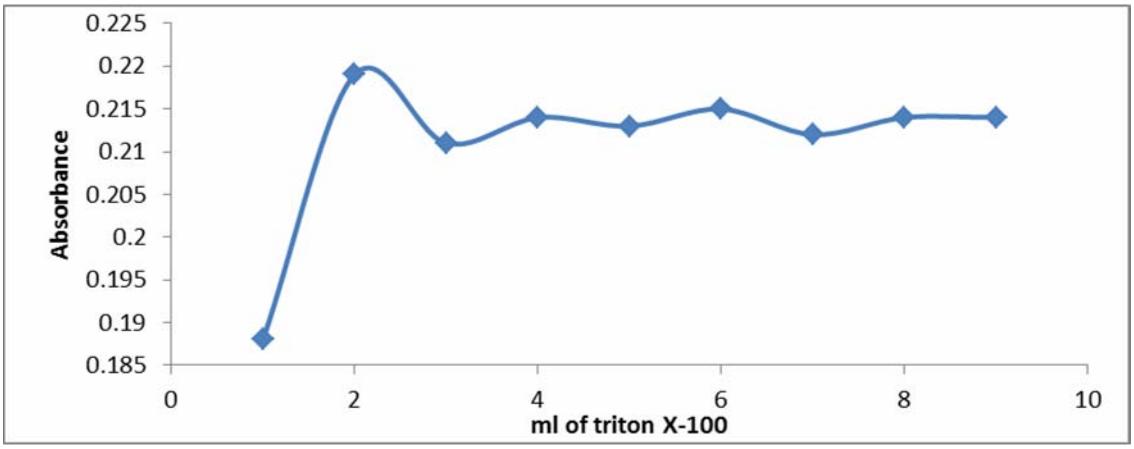


Fig. 2: Effect of amount of triton X-100

Order of addition and stability of complex

To the metal ion solution (M), each of buffer solution (B), and xylenol orange solution (R) added in possible orders. Experiments have showed that the order of addition (M+ B+R) gives the best absorbance. The addition of 2 ml triton X-100 increases the reaction stability and decreases the absorbance of corresponding reagent blank, therefore the order (M+ B+T+R) which gives the best absorbance was selected for subsequent experiments. The time for reaching maximum absorbance for the coloured complex was only 1 minute and the absorbance remains maximum and stable for at least 24 hours in the presence of triton X-100 and just 40 minutes in the absence of triton x-100 Fig. (3).

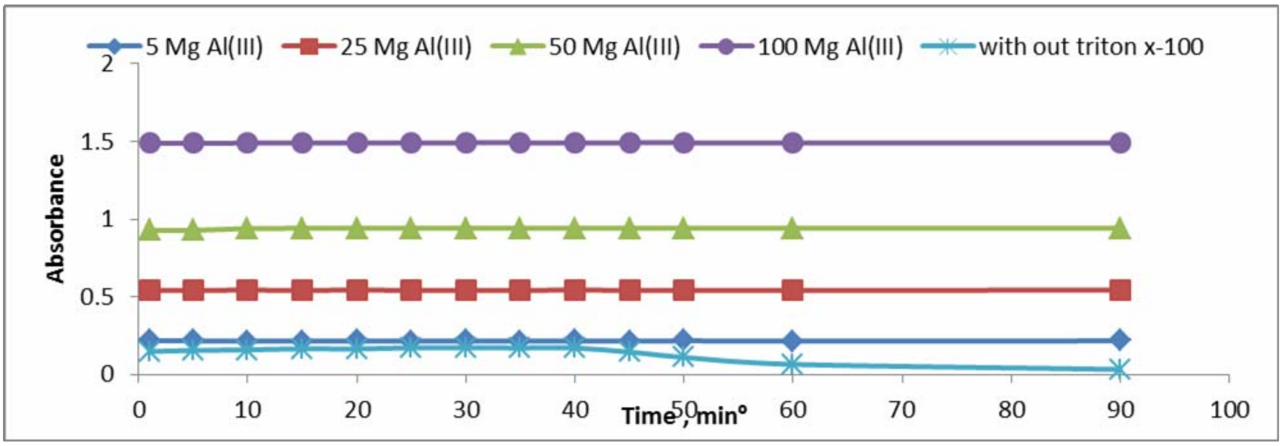


Fig. 3: Stability of complex

Final Absorption Spectra

Absorption spectra of the coloured complex aluminium-xylenol orange- triton X-100 in the presence of KH-phthalate buffer solution at pH 4.3 against its corresponding reagent blank shows maximum absorption at 512 nm in contrast to the xylenol orange reagent blank Fig. (4).

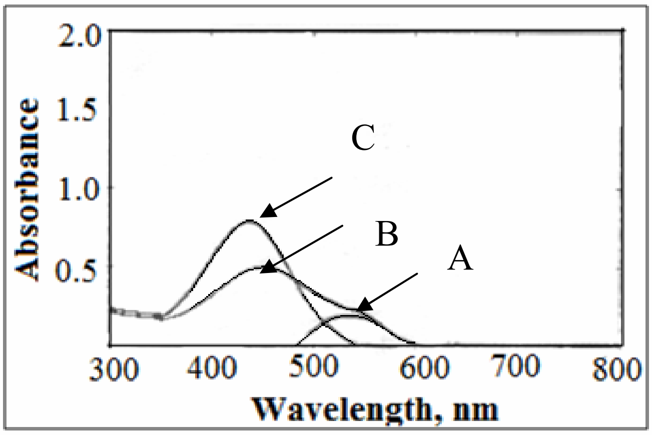


Fig. 4: Absorption spectra of 5µg of aluminium in the presence of triton X-100 /25 ml measured (A) against reagent blank (B) against distilled water, and(C) blank against distilled water.

Accuracy and precision

Under the experimental conditions which included in the recommended procedure, the recovery and precision of the method have been checked by performing five replicate determination for 5,50,100 µg of aluminium, the recovery and relative standard deviation are shown in (Table 7), indicating that the method has a good accuracy and precision.

Table 7 : Accuracy and precision

Amount of aluminium taken, µg/25ml	Recovery*, %	Relative standard deviation*, %
5	99.63	± 0.00083
50	99.79	± 0.0011
100	99.91	± 0.00084

- Average of five determinations.

Nature of the coloured complex

Job's method of the continuous variations and mole ratio (Hauser, 2004) method under the established condition have been used to study the stoichiometry of the complex aluminium - xylenol orange reagent. The results in both methods Figs. (5 and 6) show that the molar ratio of Al^{+3} to XO in the complex was found to be 1:2.

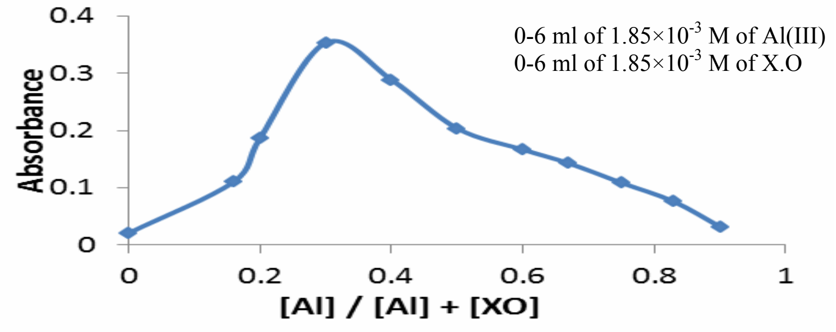


Fig.5: Job's plot for Al-XO

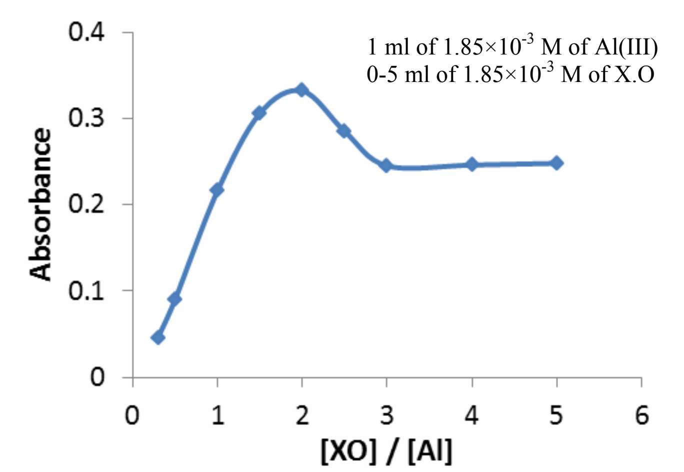


Fig. 6: Mole ratio's plot for Al-XO.

Effect of foreign ions

The effect of many foreign ions on the determination of 5 µg aluminium per 25 ml of solution was examined under the experimental conditions used. The results obtained were summarized in (Table 8).

Table 8: Effect of foreign ions

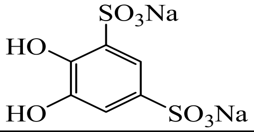
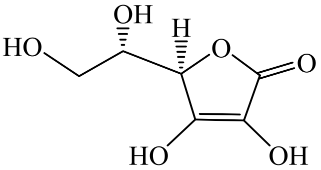
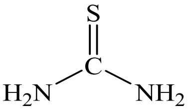
Foreign ion	Form added	Interference %			
		50	100	250	500
SO_3^{-2}	Na_2SO_3	-6.54	-5.14	-4.21	-3.27
NO_2^-	$NaNO_2$	-0.92	-0.88	-0.97	-1.07
NO_3^-	$NaNO_3$	-0.73	-0.76	-.085	-0.83
$CO_3^=$	Na_2CO_3	-0.53	-0.51	-0.56	-0.58
$S_2O_3^=$	$Na_2S_2O_3.5H_2O$	-0.99	-1.07	-1.22	-1.37
PO_4^{-3}	$NaH_2PO_4.2H_2O$	-1.93	-2.11	-2.25	-2.28
Ca^{+2}	$CaSO_4$	-0.41	-0.41	-0.43	-0.43
Mg^{+2}	$Mg SO_4.7H_2O$	-0.55	-0.57	-0.59	-0.59
Li^+	$Li_2SO_4.H_2O$	-0.82	-0.94	-1.08	-1.31
Fe^{+3}	$Fe(NO_3)_3.5H_2O$	+42.65	+56.87	+71.56	+84.36
Fe^{+2}	$FeSO_4.7H_2O$	-2.14	-2.19	-2.25	-2.28
Co^{+2}	$Co(NO_3)_2.6H_2O$	-1.82	-1.88	-1.89	-1.91
Hg^{+2}	$Hg(NO_3)_2.H_2O$	-0.87	-0.92	-0.94	-0.97
Cd^{+2}	$Cd(CH_3COO)_2.H_2O$	-0.77	-0.81	-0.88	-0.92
Pb^{+2}	$Pb(NO_3)_2$	-1.03	-1.10	-1.14	-1.18
Be^{+2}	$BeSO_4.4H_2O$	-1.93	-4.25	-9.33	-17.81
Cr^{+3}	$CrCl_3.6H_2O$	-0.86	-0.93	-0.99	-0.98
Ti^+	TiCl4	-2.06	-2.33	-2.59	-2.98
Si^+	$Na_2SiO_3.5H_2O$	-1.26	-1.33	-1.49	-1.68
Ni^{+2}	$NiCl_2.6H_2O$	-0.59	-0.77	-0.91	-1.10
Mn^{+2}	$MnCl_2.4H_2O$	-0.15	-0.32	-0.50	-0.65
Cu^{+2}	$CuSO_4$	-0.31	-0.39	-0.61	-0.74

The method seems to be moderately selective, except towards Fe^{+3}, and Be^{+2} at high concentration. In case of the higher concentration of beryllium possess many properties similar to aluminium and its compounds (Hotzbecher *et al.*, 1976).

Determination of aluminium in the presence of iron (III):

The proposed method was developed for determining aluminium in the presence of ferric ions choosing sodium cyanide as a suitable masking agent for ferric ion. The results are shown in (Table 9).

Table 9: Effect of choosing the best masking agent for iron(III)

Masking agent (0.01 M)		**Absorbance**
Name	**Structure**	
Tiron		0.097
Ascorbic acid		0.109
Sodium cyanide	NaCN	0.213
Thiourea		0.184
Thiosulphate	$Na_2S_2O_3.5H_2O$	0.178
Phospate	$NaH_2PO_4.2H_2O$	0.163

To mask the ferric ion, sodium cyanide was used as masking agent for this purpose. Therefore, different volumes (1.0-3.0) ml of (0.01 M) sodium cyanide solution were added to a solution containing a mixture of 5 µg aluminium and different amounts (10-500 µg) of ferric ions then 3 ml of buffer solution, 2 ml of triton X-100 (1%) and 2 ml of 1×10^{-3} xylenol orange. The results are given in (Table 10) indicate that 2 ml of 0.01 M sodium cyanide solution are suitable to prevent the interference caused by Fe^{3+} ions.

Table 10: Determination of aluminium in presence of iron(III)

ml of NaCN 0.01 M solution	**Absorbance / µg of Fe(III) Present**					
	10	**50**	**100**	**200**	**300**	**500**
1.0	0.266	0.354	0.363	0.386	0.399	0.472
1.5	0.243	0.264	0.289	0.310	0.344	0.374
2.0	0.215	0.213	0.211	0.216	0.219	0.217
2.5	0.199	0.198	0.210	0.216	0.227	0.233
3.0	0.173	0.184	0.196	0.211	0.212	0.215

Application of the method

The proposed method was applied to determine aluminium in various water samples. On applying procedure, good recovery is obtained as shown in (Table 11).

Table 11: Determination of aluminium in various water samples

ml of water sample	Aluminium added, µg	Recovery(%) of aluminium			
		Tap water	Tigris water*	Sea water**	Well water***
3	5	101.42	99.94	99.92	99.93
5		100.21	99.90	99.95	98.97
7		101.37	99.97	100.11	98.84
3	50	101.89	99.96	101.10	100.91
5		99.94	100.04	100.28	101.42
7		99.89	100.01	100.34	101.63
3	100	100.47	99.97	100.16	99.97
5		100.01	99.96	100.63	99.98
7		99.93	100.08	100.77	99.92

*Tigris water in Mosul city/Iraq.
** Sea water from middle east sea in Turkey.
***Well water from al-Shurra village in Mosul /Iraq.

The performance of the proposed method was assessed by calculating the student t-test (Christian, 2004) with the literature method (Park and Cha, 2000; Eder *et al.*, 2015). The results in (Table 11) show that the calculated "t" values for five degrees of freedom (N1+N2-2) at the 95% confidence level do not exceed the theoretical level t value (2.571), indicating that there is no significant difference between the proposed method and the reported method.

Table 12: The value of "t" test of natural waters

Sample	Recovery* (%)		"t" exp.
	Present method	Reported method (Park and Cha, 2000)	
Tap water	100.01	100.32	0.0239
Sea water	99.98	99.65	1.403
Tigris water	100.53	99.98	0.1413
Well water	99.93	99.91	1.236

Comparison of method

(Table 13) shows the comparison of some analytical parameters for literatures spectrophotometric methods for Aluminum (III) determination with proposed method. It can be seen from (Table 13) that the proposed method is a moderately sensitive method for Aluminum determination.

Table 13: Comparison of methods

Analytical parameter	**Present method**	**Literature method (Saritha and Reddy 2014)**	**Literature method (Eder *et al.*, 2015)**	**Literature method (Carpani *et al.*, 2004)**
λ_{max} (nm)	512	390	510	554
pH	4.3	3.0-7.0	4.5	-----
Buffer	KH-phthalate	Sodium acetate-acetic acid	Sodium acetate-acetic acid	-----
Reagent	Xylenol orange	5-Bromo-2-hydroxy-3-methoxy benzaldehyde-p-hydroxybenzoic hydrazone	Alzarin red S	Xylenol orange
Medium	Aqueous	Di methyl formamide	Aqueous	Aqueous
Surfactant	triton X-100	------	Polyvinylpyrrolidone 40	
Beer's law range ($\mu g.ml^{-1}$)	0.04-8.0 $\mu g.ml^{-1}$	0.053-0.755	5.0-320	0.14-1.8
ε ($l.mol^{-1}.cm^{-1}$)	1.173×10^4	2.66×10^4	------	2.45×10^4
Sandell's sensitivity ($\mu g.cm^{-2}$)	0.00230	0.00104	------	1.1×10^{-3}
RSD, %	± 0.0011 to ± 0.00084	0.0075	4%	-----
Interference	Fe^{+3}	Ni^{+2}, Fe^{+3}, Cu^{+2},Ti^{+4}	Fe^{+3}, Ca^{+2}	-----
Masking agent	Sodium cyanide	Iodide and EDTA	Ascorbic acid for Fe^{+3} L-Histidine for Ca^{+2}	-----
Application of method	Sea water, Tigris water, Well water and Tap water	silicate minerals, industrial sludges, soil samples plant extracts, hair, tea and water samples.	Hemodialysis water	synthetic samples of hydrotalcite

CONCLUSION

The development of simple, sensitive, moderately selective and inexpensive spectrophotometric method for the determination of Aluminum in different water samples has been carried out, using xylenol orange reagent. The complex formed was stable, water soluble and has a maximum absorption at 512 nm with molar absorptivity of 1.173×10^4 $l.mol^{-1}.cm^{-1}$ and Sandall's sensitivity of 0.00230 $\mu g.cm^{-2}$ in presence of triton X-100 while the values of molar absorptivity and Sandell's sensitivity 1.045×10^4 $l.mol^{-1}.cm^{-1}$, 0.00258 $\mu g.cm^{-2}$ respectively in absence of triton X-100.

The inteferred of iron (III) ions can be removed by adding 0.01 M sodium cyanide as a masking agent, Beer's law is obeyed in the concentration range from 0.04-8.0 μg/ml (in presence of triton X-100) and 0.2-4.0 μg/ml (in absence of titon X-100) of Aluminum. The proposed method has been applied successfully to the determination of Aluminum in different water samples.

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