

Flow- Injection Spectrophotometric Determination of some Sulpha Drugs via Oxidative Coupling with 4-Amino-N, N-diethylaniline. Application to Various Samples



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Abstract

A flow injection spectrophotometric method is described for the determination of sulphonamides in aqueous and biological samples. The method is based on the oxidative coupling reaction of 4-amino-N, N-diethylaniline with sulphonamide drugs in the presence of potassium dichromate as oxidizing agent. Intense violet, water soluble dye was obtained which has a maximum absorption at 550nm. Linear calibration graphs were obtained for different sulphonamides with a molar absorptivity of 4200-5270 l mol⁻¹ cm⁻¹ and a relative standard deviation less than 0.56%. The proposed method has proved to be highly sensitive (detection limit range 0.30-0.63 µg ml⁻¹ sulphonamide) and accurate (recovery % was 98.2-101.2%). The nature of the coloured dye and its stability constant were determined. The method was applied successfully to the determination of sulphonamide drugs in pharmaceutical preparations, blood and urine samples.

Keywords: FIA, Spectrophotometer 4-amino-N, N-diethylaniline

Introduction

Sulphonamides are widely used in the treatment of urinary tract infection burn therapy, conjunctivitis and chloroquine resistant malaria. They are also the drugs of choice for the treatment of nocardiosis toxoplasmosis, severe travellers diarrhea and meningococcal infections [1].

Various methods have been reported for the determination of sulphonamides. These include gravimetric [2,3], titrimetric [4], potentiometric [5], amperometric [6], polarographic [7], chromatographic [8], flame spectroscopic [9], fluorimetric [10] and spectrophotometric methods [11-14].

Colorimetric methods based on diazotisation and coupling with phenols or arylamines such as N-(1-naphthyl)ethylene diamine (Bratton and Marshall reagent). The latter seems to be the most popular method [15,16].

The object of the investigation reported in this paper is flow-injection spectrophotometric method for the determination of some sulphonamide drugs in an aqueous medium using 4-Amino N, N-diethyl aniline as a chromogenic reagent and potassium dichromate reagent as oxidant. The application of the method for the analysis of drugs in blood, urine and pharmaceutical samples are also considered.

Experimental

Apparatus and flow manifold

Fig.(1) shows the manifold used for the flow-injection spectrophotometric determination of sulphonamides . The manifold consists of a peristaltic pump(p) of the type (Desaga He- idel Berg, England) with six channels.

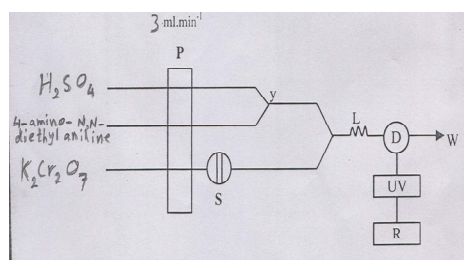


Fig (1):Schematic diagram of the flow-injection manifold for determination of sulphonamides.

A sample injection via a rotary valves (type Rehodyne, U.S. A) with a sample loop as used to inject the sample volume into the flowing carrier stream. Teflon tubes and mixing (reaction) coil (L) of 0.88 mm i.d. were used in this flow manifold and a home made (Y) piece (Perspex) was used to mix the reagents.

A spectrophotometric detector (D) and 4050 uv-visible single beam linear readout provided with 60- μ l flow through cell. DC-microvoltmeter (μ v) for increasing sensitivity. A power supply was used. A single pen x-t recorder (R) was used.

Reagents

All chemicals used were of analytical reagent grade. All sulphonamide drugs were obtained in a highly pure form and pharmaceutical preparations from the state drug industry (SDI), Sammara-Iraq.

Standard sulphonamide (500 μ g ml⁻¹) solutions : were prepared by weighing accurately 100mg of each sulpha drug., dissolved in 10 ml absolute ethanol and diluted to 200 ml in a volumetric flask with distilled water.

4-amino-N,N- diethylamine monohydrochloride solution (5 x 10⁻³ M)

0.2187 g of pure 4-amino-N,N-diethylaniline monohydrochloride was dissolved in 200 ml of absolute ethanol.

This solution should be prepared daily and stored in a dark bottle.

Potassium dichromate solution (4x 10⁻³ M): 0.2354 g of potassium dichromate was dissolved in 200 ml distilled water.

Recommended procedures

Procedure for calibration curves

5 x 10⁻⁴ M 4-amino-N, N-diethylaniline, 0.5M potassium dichromate and at 0.1M H₂SO₄ at a flow rate 3 ml/min (Fig.1) increasing volumes of sulphonamide working solution (100 μ g/ml) were injected. The absorbance was measured at 550 nm against reagent blank, prepared in the same way but containing no sulphonamide using 1-cm cells. In all subsequent experiments, 100 μ g/ml of sulphonamide as sulpanilamide and sulphadiazine were used. The absorbance is plotted against the final concentration to obtain a calibration curve.

Procedure for tablets [17]

20 tablets were finely powdered and weighed accurately. A portion of the powder equivalent to about 100mg of the sulphonamide, was extracted with 10ml of absolute ethanol. The solution was warmed and then, the mixture was filtered and washed with 5 ml ethanol. The combined filtrate and washings were diluted to 200ml with distilled water (final concentration was 500 μ g ml⁻¹). 10 ml of this solution was diluted to 100 ml with distilled water to obtain 50 μ g ml⁻¹, 10 μ l of the latter solution was injected into 4-amino-N, N-diethylaniline line (Fig.1) using the optimum conditions, and the absorbance peak height was measured.

Procedure for Prednisolone-s eye drops [17]

Five bottles of the prednisolone-s were mixed together and 1ml of the prednisolone-s [10% sulphacetamide

sodium (SAC)] which contains 10 mg of sulphacetamide was mixed with 10ml of ethanol and then diluted to a final volume of 200ml SAC. $50 \mu\text{g ml}^{-1}$ solution was prepared by dilution of 10 ml of $500 \mu\text{g ml}^{-1}$ to 100 ml with distilled water. The latter solution was injected into 4-amino-N, N-diethylaniline line (Fig. 1).

Procedure for blood sample [17]

2ml of serum was mixed with 30 ml of distilled water and 8 ml of 15% trichloro acetic acid, and then centrifuged for 5min at a speed of 3000 rpm, and the supernatant liquid was filtered. For the determination of free sulphonamide in the blood, the supernatant liquid was injected into the 4-amino-N, N-diethylaniline line (Fig.1). the absorbance peak height of the solution was recorded at 550 nm.

For the determination of total sulphonamide (Free and conjugated) 0.5 ml of 2M HCl was added to 10 ml of the supernatant liquid (after precipitation of protein), then heated on a boiling water bath for 1 hour. The solution was cooled and adjusted to a volume of 10 ml, then proceeding as for the determination of free sulphonamide.

Procedure for urine sample [17]

The urine sample was diluted five times with distilled water and the diluted urine solution was used for further experiments. For the determination of free sulphonamide in urine , 2ml of the diluted urine was mixed with 30 ml of water and 8ml of 15% trichloroacetic acid. The solution filtered and the supernatant liquid was injected into the 4-amino-N,N-diethylaniline line (Fig.1).

The absorbance peak height of the solution was recorded at 550 nm. For total sulphonamides (free and conjugated) after precipitation of protein, 5ml of the diluted urine was placed in a 100 ml volumetric flask, 5ml of 4M HCl was added and the solution was diluted to the mark with distilled water, 10ml of this solution was heated in a boiling-water bath for 1 hour,

cooled and the volume adjusted to a 10 ml , and the procedure was followed as for sulphonamides.

Results and Discussion

The reaction of sulphonamides with 4-amino-N, N-diethylaniline in the presence of potassium dichromate produced highly coloured violet condensation product with a maximum absorption at 550nm (Fig. 2). The absorbance of the coloured product was measured using flow injection analysis (FIA) system [Fig.(1)].

Initial studies were directed toward optimization of the experimental conditions in order to obtain a good sensitivity, stability and reproducibility of the coloured product. The influence of various reaction variables on the coloured product was tested to establish the most favourable conditions for the determination of $50 \mu\text{g ml}^{-1}$ sulphonamide as an underivatized sulphonamide and sulphadiazine as an example of derivatized sulphonamide. Each sample was injected three times and the average peak height in mV is presented.

Optimization of conditions

A-chemical optimizations

Sulphuric acid concentration

Table(1) tabulates the variation of H_2SO_4 concentration (M) versus peak height(mV). A concentration of 0.1M was found optimum and was used throughout the work.

4- Amino-N, N-diethylaniline concentration

Using optimized H_2SO_4 concentration at 0.1 M and keeping all other chemical concentrations and physical parameters constant as indicated in the preceding section, effects of different 4-amino-N, N-diethylaniline concentrations are investigated. Table (2) shows the results; it is found that 1×10^{-4} M gives most sensitive signal.

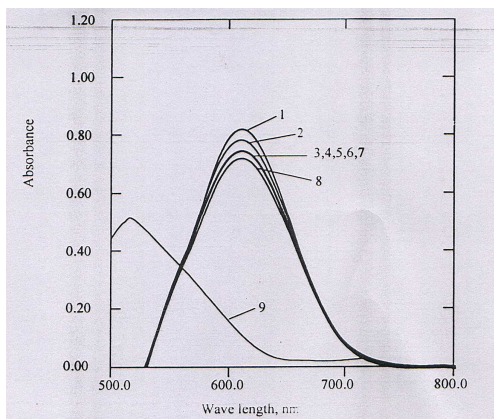


Fig.(2): Absorption spectra of the product obtained by the injection of 50µg ml⁻¹ sulphonamides into a stream of 1 x 10⁻⁴ M 4-amino-N,N-diethylaniline, mixed with 2 x 10⁻⁴ M K₂Cr₂O₇ of

- 1-Sulphanilamide, 2- Sulphacetamide sod.,
- 3- Sulphaguanidine, 4- Sulphamerazine,
- 5- Sulphadiazine, 6- Sulphamethoxazole,
- 7- Sulphathiazole,, 8- Sulphadimidine,
- 9- Absorption spectra of blank solution.

Table(1): effect of H₂SO₄ concentration

Concentration of sulphuric acid(M)	Absorbance expressed as average(n=3) peak height	
	sulphanilamide	sulphadiazine
0.00	121	92
0.1	316	283
0.2	300	271
0.3	230	155
0.4	200	135
0.5	165	110

Table(2): Effect of 4-amino-N, N-diethylaniline concentration.

Concentration of 4-amino-N,N-diethylaniline(M)	Absorbance expressed as a verage (n=3) peak height	
	sulphanilamide	Sulphadiazine
1 x 10 ⁻⁵	125	96
1 x 10 ⁻⁴	320	290
5 x 10 ⁻⁴	305	276
1 x 10 ⁻³	210	145

Potassium dichromate concentration

Using Optimised H₂SO₄ (0.1 M), 4- amino-N, N-diethylaniline (1 x 10⁻⁴ M), and other conditions mentioned in various sections, effect of different potassium dichromate concentrations is investigated. The results are given in Table (3) , it is found that 2 x 10⁻⁴ M gave the best significant results.

B- Physical optimizations

Length of delay reaction coil

Using the optimum concentration of reactants, different lengths of delay reaction coil (220-400)cm were tested.Fig.(3) shows that 320 cm coil length gives the best significant results. Longer reaction coil caused more sample dispersion [18]. Longer diameter coil was avoided to prevent excessive reagent consumption [19]. Therefore, 0.88 cm was selected and used through out the work.

Table (3): Effect of potassium dichromate concentration.

Concentration of potassium dichromate (M)	Absorbance expressed as a verage (n=3) peak height	
	sulphanilamide	Sulphadiazine
2 x 10 ⁻⁵	130	98
5 x 10 ⁻⁵	320	295
1 x 10 ⁻⁴	325	298
2 x 10 ⁻⁴	330	300
2 x 10 ⁻³	215	145

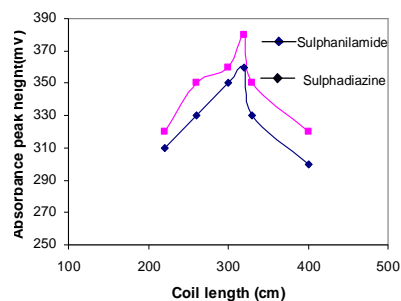


Fig.(3): Effect of coil Length

Flow- rate

The FIA system (Fig. 1) was operated at different flow rates (2-10 ml min⁻¹), and it was found that 3 ml min⁻¹ is the optimum flow-rate (Fig.4).

Sample Volume

Different sample volumes (60-180 µl) were tested. The results obtained (Table 4) showed that 60 µl is the optimum sample volume , and was used throughout the work.

Effect of Temperature

Table (5) indicated that the absorbance of the coloured product when carried out at 0°C decreases in the reaction rate. Also the reaction was carried out at 50°C, the absorbance also decreased, which probably due to partial decomposition of the product. Therefore, the reaction mixture should be carried out at room temperature(25°C). The optimum working conditions are tabulated in Table (5).

Calibration graph

The results for calibration graphs of sulphonamides obtained under the optimized conditions using the FIA manifold are illustrated in Table (7). Intense violet water soluble dye was obtained which has a maximum absorption at 550nm . It appears from the results that the slopes of the calibration graphs vary considerably. This is probably due to the difference in the reaction rate and different substituents of each sulphonamide, therefore, individual working calibration graphs are required and so that the method can be applied only to samples containing one sulphonamide. Sulphanilamide, the simple molecule , has the fastest reaction, probably because the

other sulphonamides are sterically hindered [20].

A t-test is conducted for linearity relation and it shows that $t_{cal} = 520.19$ compared with $t_{tab} = 2.23$ at 95% confidence limit . which indicates rejection of H_0 (non linearity) against alternative hypothesis (linearity). The linear regression equation for the range of concentration 0.8-80.0 µg ml⁻¹ sulphanilamide at 95% confidence limit is $Abs. (av.pk. hgt. (n=3))mV = (5.236(\pm 0.235) + (4.352 \pm 0.017) \text{ sulphanilamide}) \mu\text{g ml}^{-1}$.

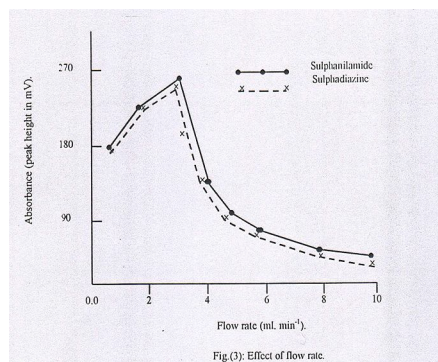


Fig.4: Effect of Flow Rate

(µl)	sulphanilamide	sulphadiazine
60	335	300
80	300	285
100	290	270
120	275	260
140	270	265
130	260	255
140	250	240
180	240	235

Table(4): Effect of sample volume

Table (5): Effect of temperature

Temp. (°C)	Absorbance expressed as average(n=3) peak height	
	sulphanilamide	sulphadiazine
0	195±1.23	180±1.07
10	200±1.65	185±1.11
15	260±1.23	250±1.25
25	337±1.1	302±1.05
30	300±1.72	290±1.1
40	290±1.06	280±1.07
50	250±1.52	240±1.1

Table (6): Optimum working conditions for spectrophotometric determination of sulphonamide by FIA system using 4-amino N,N-diethylaniline and potassium dichromate.

Parameter	Value
Flow rate	3ml min ⁻¹
Reaction coil length	320cm
Sample volume	60µl
Sulphuric acid concentration	0.1 M
K ₂ Cr ₂ O ₇ conc.	2 x 10 ⁻⁴ M
4-amino-N, N-diethyl aniline con.	1 x 10 ⁻⁴ M
Wave length selected	550 nm
Temperature	25°C
Reaction tubing diameter	0.88 measured i.d

Precision and accuracy

Using the optimum conditions (Table 6), the precision for the determination of sulphonamides by FIA was studied. Table 8 shows the values of the relative standard deviation (R.S.D) for five injections of each sulphonamide containing 10, 30 and 50 µg ml⁻¹ sulphonamides.

For estimation the accuracy of the method, five injections were performed containing 30 µg ml⁻¹ of each of the sulphonamide of the same solution investigated. The results obtained indicated that the average recovery is between 98.2% and 101.2%.

Nature of the product [21]

Mole-ratio method for the determination of stoichiometry of dye was adopted to flow techniques. First stream containing sulphonamide (1 x 10⁻⁴ M) in 0.1 M H₂SO₄, second stream containing variable concentrations of 4-amino-N, N-diethyl aniline and third stream containing K₂Cr₂O₇ (0.5 M) were passed through the flow system. The absorbance peak height were measured and proved the existence of a 1:2 sulphonamide : 4-amino-N,N-diethylaniline reagent. The stability constant (K stab.) can be calculated using the following equation [20]:

$$K_{\text{stab}} = \frac{a - \Delta A / \varepsilon}{n^n (\Delta A / \varepsilon)^{n+1}}$$

Where a=concentration of sulphonamide
ε= molar absorptivity, n= mole ratio

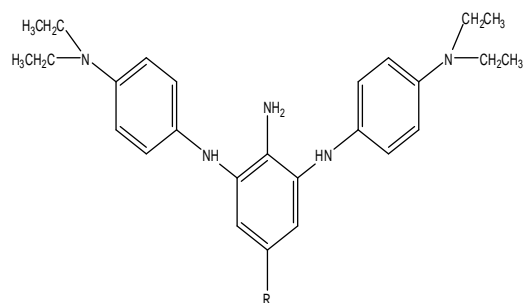
$$\Delta A = A_m - A_s$$

A_m = absorbance of a solution containing sulphonamide five times excess than the amount of 4- amino N, N-diethylaniline.

A_s= Absorbance of a solution containing a stoichiometric amounts of sulphonamide and 4-amino-N, N-diethylaniline.

The conditional stability constants of different sulphonamide products are summarized in Table (9).

Therefore, the structure of the dye may be written as follows



R= -SO₂-NH-R'

Table(7); Spectal characteristics of products from the reaction of sulphonamides with 4-amino-N, N-diethylaniline and potassium dichromate by automated FIA.

Sulphonamides	Detection limit ($\mu\text{g ml}^{-1}$)	Σ max(l $\text{mol}^{-1}\text{cm}^{-1}$)	Linear range ($\mu\text{g ml}^{-1}$)	Intercept (mV) ($a\pm tsa$)	Slope mm.ml μg $a\pm tsa$	Correlation coefficient (r)
Sulphanilamide	0.40	3.40×10^3	0.6-80.0	3.37 ± 0.02	2.465 ± 0.010	0.9999
Sulphadiazine	0.54	3.65×10^3	0.5-75.0	3.61 ± 0.01	2.567 ± 0.020	0.9996
Sulphagunidine	0.58	3.20×10^3	2.0-90.0	3.76 ± 0.030	2.765 ± 0.020	0.9997
Sulphacetamide sodium.	0.35	3.82×10^3	0.6-100.0	3.86 ± 0.04	2.675 ± 0.030	0.9993
Sulphamera zine	0.63	3.44×10^3	1.0-100.0	3.45 ± 0.050	2.685 ± 0.040	0.9998
Sulphamethaxazol	0.56	4.33×10^3	2.0-100.0	3.45 ± 0.040	2.753 ± 0.060	0.9993
Sulphathiazole	0.32	3.62×10^3	2.0-100.0	3.65 ± 0.060	2.353 ± 0.050	0.9995
sulphadimidine	0.30	5.27×10^3	1.0-100.0	3.33 ± 0.060	3.35 ± 0.030	0.9999

at 99% confidence limit

Table (8): Precision of the method

Compound	R.S.D%		
	$10\mu\text{gml}^{-1}$	$30\mu\text{gml}^{-1}$	$50\mu\text{gml}^{-1}$
Sulphonamides	0.64	0.45	0.35
Sulphanilamide	0.45	0.35	0.30
Sulphadiazine	0.43	0.31	0.20
Sulphagunidine	0.32	0.22	0.10
Sulphacetamide sod.	0.50	0.41	0.22
Sulphamera zine	0.42	0.44	0.32
Sulphamethaxazol	0.33	0.50	0.32
Sulphathiazole	0.48	0.43	0.32

Analytical applications:

Sulphonamides are usually formulated in tablet form, therefore the effect of common tablet excipients and additives on the procedure was investigated. It was found that glucose, lactose, sucrose, starch and magnesium stearate had no effect on the assay Table (10).

The effect of other drugs which are commonly prescribed with sulpha drugs e.g., chloromphenicol, phthalyl sulphathiazole and succinyl sulphathiazole

were also investigated and it was found that non of these drugs interfere.

Table (11) shows that the results obtained from the determination of sulph drugs in some of their dosage forms by means of the proposed method, indicate that the method has a good recovery (98.6-101.2%) except for trimethoprin, (147.0% recovery) since it contains an additional primary aromatic amine. A satisfactory results (Table 12) were obtained for the analysis of blood and urine samples;

Table (9): the stability constant of the products obtained by the reaction of sulphonamides with 4-amino-N,N-diethylaniline and $K_2Cr_2O_7$.

Compounds	Stability constant $l^2.mol^2$
Sulphonamides	1.86×10^9
Sulphanilamide	1.73×10^9
Sulphadiazine	1.99×10^9
Sulphagunidine	2.3×10^9
Sulphacetamide sod.	3.4×10^9
Sulphamerazine	3.3×10^9
Sulphamethaxazol	2.1×10^9
Sulphathiazole	4.1×10^9

Table(10): Effect of excipients and additives on the recovery of sulphonamide drugs FIA-4-amino-N,N-diethyl aniline $K_2Cr_2O_7$ method.

Excipient	Amount add μgmm^{-1}	Amount add to know the fold excess	Amount per 10 mg of drug/mg	Sulphanilamide*		Sulphadiazine*	
				Recovery %	R.S.D%	Rec%	R.S.D
Glucose	50	60	0.3	98.6	0.41	100.5	0.85
Lactose	25	61	0.2	99.7	0.54	99.3	0.63
Sucrose	40	43	0.4	101.2	0.56	98.2	0.52
Starch	22	52	0.2	99.5	0.32	99.6	0.72
Magnesium stearate	20	50	0.2	98.6	0.40	99.3	0.50

* average of five determinations.

Table (11): Mean recovery of sulpha drugs in dosage forms by FIA. 4-amino-N,N-Diethyl aniline – $K_2Cr_2O_7$ procedure

Compound	Amount mg per ml per tablet found		Mean recovery % +
	Nominal	Present method	
Methoprim tab*	400	588	147.0
Sulphagunidine tab	500	490	98.0
Sulphadimidine tab	500	493	98.6
Prednisolones** eye drops	500	485	97.0

+ average of five determinations.

* Each tablet contains 400 mg of sulphamethoxazole and 80 mg of methoprim. Few tablets crushed, sieved then weight a known amount equivalent to one tablet weight, because no single tablet contain the some amount of active ingredient.

** Each 100 ml contain 10 g sulphacetamide sodium and 0.25 g of prednisolone-S . The Darow CO. Tahrans-Iran

Table (12): Assay of sulphonamide drugs in blood and urine using FIA4-amino-N,N-Diethyl aniline – $K_2Cr_2O_7$ procedure

Sample	Drug administered	Amount found $\mu g ml^{-1}$	
		Free	Total
Blood	Sulphanilamide	0.874 ± 0.019	1.035 ± 0.022
Blood	Sulphadiazine	0.963 ± 0.033	1.132 ± 0.045
Urine	Sulphanilamide	1.352 ± 0.055	2.053 ± 0.043
Urine	Sulphadiazine	1.562 ± 0.067	2.352 ± 0.043

* For 95% confidence limit (n=3) at $u = x \pm 1 \frac{\sigma_{n-1}}{\sqrt{n}}$

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شېكردنەۋەى تېھە ئچوونى رۇيشتوو بۇ ديارىكردى دەرمانى سەلفا بە ھۇى كرادرى ئۇكسان بەھۇى پېوھنووسانى 4- ئەمىنو N ، N- دوانە ئەسىل ئەنىلین

یوسف جلال عەزیز، بەشى كیمیا، كۆلیزى زانست، زانكۆى سەلاھەدین، ھەرىمى كوردستان \ عىراق

پوختە

تویژینەۋەكە بریتى یە ئە چۆنیەتى بەکارهینانى کارلیکی جووتبوونى ئۆكسینراو بۇ ديارىكردى برى دەرمانى سۇلفونامید ئە ناوھندى ناوی بەشەبەنگ و بەکارهینانى رییازى تیرکردنى رۇيشتوو (FIA). ریگاکەش پشت دەبەستى بە کارلیکی جووتبوونى ئۆكسینراوی سۇلفونامید ئەگەل 4-amino-N, N-diethyl aniline بە بوونى کارکەرى ئۆكسیدکەرى دایکروماتى پۆتاسیوم ئە ناوھندى ترش، بۆیەیکى وەنەوشەیی تاوۋە ئە ناودا پەیدا بوو کە بەرزترین مژینی ھەییە ئە دریزە شە پۆلى (550) نانومیتەر، ھاوکۆلکەى مژینی مۆلارى بە گویرەى سۇلفونامید ئە نیوان 2570-4200 نتر مۆل¹⁻ سم¹⁻ وئیک چوون ئە $0.5 \pm$ % باشتربوو، کەمترین برى ديارىکراو ئە نیوان 0.30-0.63 مایکروگرام بۆھەر میلیتریک ئە سۇلفونامید، ریزەى دووبارەبوونەۋە ئە نیوان 98.2 بۇ 101.2% دا بوو، ھەرۋەھا تویژینەۋەكە کارى تیزوۋەکانى ديارى کرد ئەسەر ریگاکە . ھەرۋەھا سروشتى بۆیە پەیدا بوەكە بە ریگەى ریەى مکزۆى بەکارهینانى FIA ديارى کرا. ریگاکە بە سەرکەوتوویى بەکارهینرا بۇ ديارىكردى سۇلفونامید ئە خوین و میز و پیکهاتوۋە دەرمانگەیی بەکان بە تیكرای 40 نمونە ئە کاترمیریکدا.

تحليل الحقن الجرياني لتقدير أدوية سلفا من خلال تقنية أكسدة اقتران مع -امينو- N ، N – داي ايثايل انيلين
يوسف جلال عزيز، قسم الكيمياء، كلية العلوم، جامعة صلاح الدين، اقليم كردستان \ العراق

الخلاصة

تضمن البحث إمكانية استخدام تفاعلات الأزواج التأكسدي لتقدير أدوية السلفوناميد في الوسط المائي طيفياً و بتقنية الحقن الجرياني. أعمدت هذه الطريقة على تفاعلات الاقتران التأكسدي ل-4-امينو- N، N- داي ايثايل انيلين مع ادوية السلفوناميد بوجود دايكرومات البوتاسيوم كعامل مؤكسد لأعطاء صبغة مستقرة ذات لون بنفسجي ذاتية في الماء لها أعلى امتصاص عند طول موجي مقداره 550 نانوميتر، تم دراسة جميع المتغيرات الكيميائية والفيزيائية للتوصل الى الظروف المثلى حيث تم الحصول على منحنيات المعايرة للسلفوناميدات المختلفة. تراوح معامل الامتصاص المولاري للطريقة بين 4200-5270 ليتر . مول¹⁻ سم¹⁻ و التوافقية افضل من $0.50 \pm$ % . وبلغ أدنى حد للكشف بين 0.30 الى 0.63 مايكروغرام لكل ملتر سلفوناميد ونسب الاستعادية بين 98.2 الى 101.2 %، وشمل البحث أيضاً دراسة تأثير المتداخلات على طريقة التقدير. ودرست طبيعة الصبغة الناتجة بطريقة لنسب المولية و بتقنية الحقن وكذلك طبقت الطريقة بنجاح في تقدير أدوية السلفوناميد في نماذج الدم والادرار و المستحضرات الصيدلانية.

Received ,11 /9/2007 , Accepted on 5/11/2008

وردگیراۋە ئە 11 / 9 / 2007 دا، پەسەند کرا، ئە 11/5 / 2008 دا