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Sensitive and Rapid Spectrophotometric Method for Determination of Mesnatrithiocarbonate Using Palladium (II)

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Abstract:

An analytical method for spectrophotometric analysis of an anticancer medication Mesna through its derivatisation as trithiocarbonate followed by complexation with Palladium (II) is described. Mesnatrithiocarbonate forms an orange-coloured 1:2 complex with Palladium (II) that has λmax 370nm. A synthesized complex created complies with Beer's law in the concentration variety of 8.351µg/ml to 1.837 X 10^2µg/ml. The complex is stable at neutral pH at a temperature of 30°C with correlation coefficient (r) = 0.995. Characterization of the complex includes thermal analysis, elemental analysis, FTIR, 1H NMR, ESR, and Raman spectrum studies. The complex's FTIR spectra reveal the binding of the sulphur atom of the trithiocarbonate group with palladium (II). H^1 NMR studies of the complex in D_2O shows further confirm the involvement of the sulphur atom of the trithiocarbonate group in complexation with Pd (II). The absence of a signal in the complex's ESR spectrum shows the diamagnetic nature of the complex. Raman spectra of the complex show the participation of the trithiocarbonate group in bonding with the central metal atom. Thermogravimetric analysis confirms the structure of the complex.

Key Words: Mesnarithiocarbonate, Palladium (II) complex, UV spectroscopy.

1. Introduction:

Trithiocarbonates are derivatives of thiols which have high reactivity due to their versatile nature of reacting both with electrophilic and nucleophilic reagents. Trithiocarbonate (TTC) is a significant chemical molecule that has applications in nanotechnology and surface colloid research [1]. (TTC) is a significant chemical molecule that has applications in nanotechnology and surface colloid research [2]. Trthiocarbonate derivatives of organic compounds play an important role in various synthesis reactions and medical applications. When a medication is coupled with metal, it derivatizes to its trithiocarbonate moiety, which plays a crucial function and becomes more effective than the original molecule. During the formation of trithiocarbonate derivate, the uncoordinated sulphur atom participates actively and gets converted into sulphur alkylated cations which then form CS_3-bridged binuclear complexes [3,4]. These trithiocarbonates provide binding sites of three sulphur atoms. Trithiocarbonates are weakly acidic and consequently their transition metal complexes are neutral, which remain in non-ionised form and are thus easily assimilated into the body fluid[5-10]. The complex formed between trithiocarbonate and palladium (II) is a complex between soft acid and soft base. An FDA-approved medication called mesna (sodium 2-mercaptoethanesulfonate) has been used to lower the risk of bleeding in cancer patients receiving ifosfamide or cyclophosphamide. [11-15]. The literature review involved a few analytical procedures such as spectrophotometric [16-17] methods for quantitative estimation of mesna. Mesnatrithiocarbonate (MTTC) on reacting with palladium (II) forms the mesnatrithiocarbonate palladium (MTTCPD) complex. The developed Spectrophotometric techniques are straightforward, selective, and sensitive with no sample preparation compared to each and every documented spectrophotometric technique [18-24].

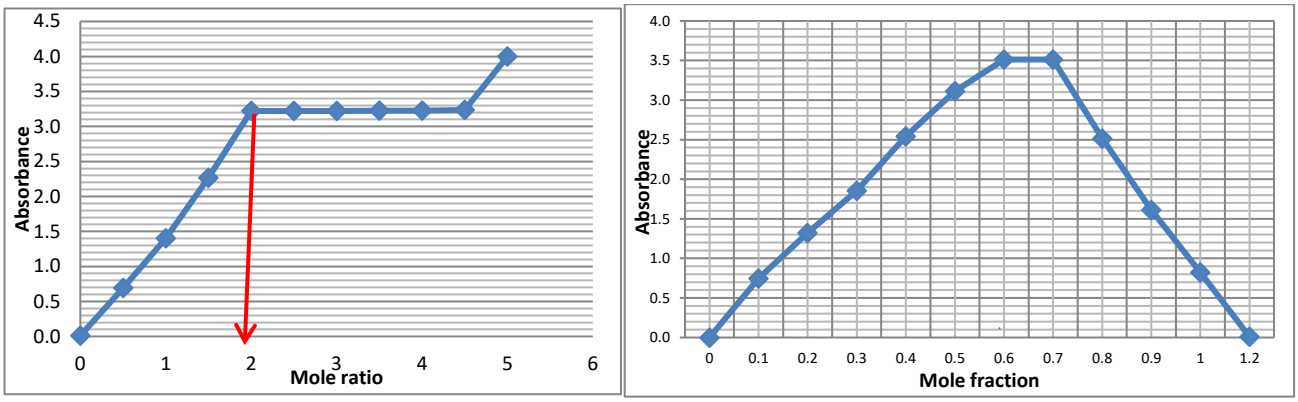
The proposed method employed for the determination of sodium-2-mercaptoethanesulphonate involves its quantitative conversion to TTC at room temperature. The trithiocarbonate of sodium-2-mercaptoethane sulphonate thus formed has been determined quantitatively using palladium (II) chloride.

2. Experimental

2.1 Instruments and reagents - For all UV-visible spectrophotometric measurements, an Elico SL-159 double-beam spectrophotometer was utilized**.** All the chemicals used were employed without additional purification, and they were of analytical quality. Using KBr pellets, the FTIR spectra were captured in the 4000-400cm-1 range using a Nicolet FTIR spectrometer. Using tetracyanoethylene as a marker, the ESR spectra were captured in a Varian ESR spectrometer within the 2000gauss scan range. Using deuterium oxide as a solvent, the 1H NMR spectra were captured on a Varian-300MHz spectrometer. Laser Raman spectrometer Ramanor HG-25 was employed to record the Raman spectrum with Argon Laser (488 nm) as irradiation source. Thermogravimetric analysis was done using the Dupont thermal analysis system under a nitrogen atmosphere at a rate of 15 °C per minute from 0 °C to 8000 °C. For the preparation of MTTC equimolar amount of carbon disulphide, potassium hydroxide and sodium 2-mercaptoethanesulphonate are mixed at 0°C till a light yellow-coloured semisolid mass is obtained, which is then dissolved in distilled water to get a standard solution. Palladium solution was prepared by dissolving $PdCl_2$ (E. Merck) in 0.25 N HCl solution in double distilled water. Aliquots of the standard stock solution were diluted to create solutions with lesser concentration.

2.2 Preparation of MTTCPD complex - An orange-coloured complex is created when MTTC solution at 30°C is mixed with palladium chloride solution. For optimal colour development and full complex formation, 60 minutes is the minimum amount of time needed, thereafter the intensity of the colour remains constant for 22 hours. The λmax of the MTTCPD complex is 370nm.

2.3. Composition of MTTCPD complex: The complex's composition was found to be 1:2 for Pd (II): sodium 2-mercaptoethanesulphonate trithiocarbonate complex by the Job's approach of continuous variance and the mole ratio method.



(a) (b)

Figure 1: (a) Mole ratio plot and (b) Job's method of continuous variation plot for MTTC-Pd (II) complex

2.4 Procedure

To different aliquots containing 8.3519 µg/ml to 1.8374 $X10^2$ µg/ml of MTTC, an excess of a molarity-based palladium chloride solution 4.0132M was added and volume was maintained constant using double distilled water. Maintaining the temperature and pH conditions absorbance of all sets was captured at the complex's λmax which is 370nm. To check for the validity of the developed method Beer's Lambert's plot was obtained to determine the unknown concentration.

3. Results and Discussion

The calibration curve for the MTTCPD complex shows a strong linear connection across the range 8.351µg/ml to 1.837$X10^2$µg/ml of MTTC with ε value 1.19 X 10^3 l mol^{-1} cm^{-1} and relative standard deviation (RSD%) ±1.227 % as given in table 1. The regression equation has an 'a' value of 3.253 X 10^{-2} and a 'b' value of 2.874 X 10^{-3}. Thus the regression equation for the MTTCPD complex is

$$Y = 3.253 \times 10^{-2} + 2.874 \times 10^{-3} X.$$

Also, the correlation coefficient (r) as calculated was found to be 0.995. The correlation coefficient illustrates how much of a reciprocal reliance exists between concentration and absorbance. As a result, using the suggested approach and knowing its absorbance, one may determine the concentration of MTTC.

S.No	ACHIEVED WEIGHT (in µg)	WEIGHT FOUND (in µg)	COEFF. OF VARIANCE	RSD %
1.	8.352 $X10^0$	7.656 $X10^0$	1.017	0.833
2.	1,670 $X10^1$	1.670 $X10^1$	0.000	0.000
3.	2.506 $X10^1$	2.645 $X10^1$	0.785	0.556
4.	3.341 $X10^1$	3.410 $X10^1$	0.294	0.208
5.	4.176 $X10^1$	4.315 $X10^1$	0.471	0.333
6.	5.011 $X10^1$	5.011 $X10^1$	0.000	0.000
7.	5.846 $X10^1$	5.846 $X10^1$	0.000	0.000
8.	6.682 $X10^1$	6.751 $X10^1$	0.329	0.104
9.	7.517 $X10^1$	7.447 $X10^1$	1.031	0.093
10.	8.352 $X10^1$	8.282 $X10^1$	0.263	0.083
11.	9.187 $X10^1$	9.257 $X10^1$	1.071	0.076
12.	1.002 $X10^2$	9.953 $X10^2$	0.098	0.069
13.	1.086 $X10^2$	1.079 $X10^2$	0.091	0.064

14.	1.169 $X10^2$	1.169 $X10^2$	0.000	0.000
15.	1.251 $X10^2$	1.246 $X10^2$	1.007	0.056
16.	1.336 $X10^2$	1.350 $X10^2$	1.047	0.104
17.	1.420 $X10^2$	1.413 $X10^2$	0.693	0.490
18.	1.503 $X10^2$	1.503 $X10^2$	0.000	0.000
19.	1.587 $X10^2$	1.594 $X10^2$	0.620	0.438
20	1.670 $X10^2$	1.663 $X10^2$	0.589	0.416
21.	1.754 $X10^2$	1.747 $X10^2$	0.561	0.397
22.	1.837 $X10^2$	1.879 $X10^2$	0.227	1.227

Table 1: Calibration data of MTTC as its Pd (II) complex

The FTIR spectra of MTTCPD complex in a solid state as Pellets of KBr were measured between 400 and 4000 cm^{-1} which shows shifting of –C=S stretching band at 1133.54 cm^{-1} to 1009.71 cm^{-1} in the spectra of trithiocarbonate due to conversion of thiol group to trithiocarbonate group [25]. In MTTCPD this band completely disappears due to the complexation of the trithiocarbonate group with palladium (II). Also, the C-S stretching band at 658.55cm^{-1}in mesna spectra is shifted to 851.37 cm^{-1}due to the e3SWconversion of –SH of thiol group into K^+-S – C – S - R in mesna TTC spectra and finally in MTTCPD it is shifted to 869.31cm^{-1} confirming the involvement of sulphur atom of trithiocarbonate group in complexation. The -S=O band gains a double bond nature that is more confined and consequently its frequency rises due to the sulphur atom's single pair of electrons being contributed to the metal in order to create a bond, but not being available to take part in the resonance. As a result, symmetric and asymmetric stretching of - S=O at 1059.82 cm^{-1} and 1216.24 cm^{-1}gets shift to 1050.78 cm^{-1} and 1195.61 cm^{-1}in the FTIR spectra of MTTCPD complex as can be seen in figure 2.

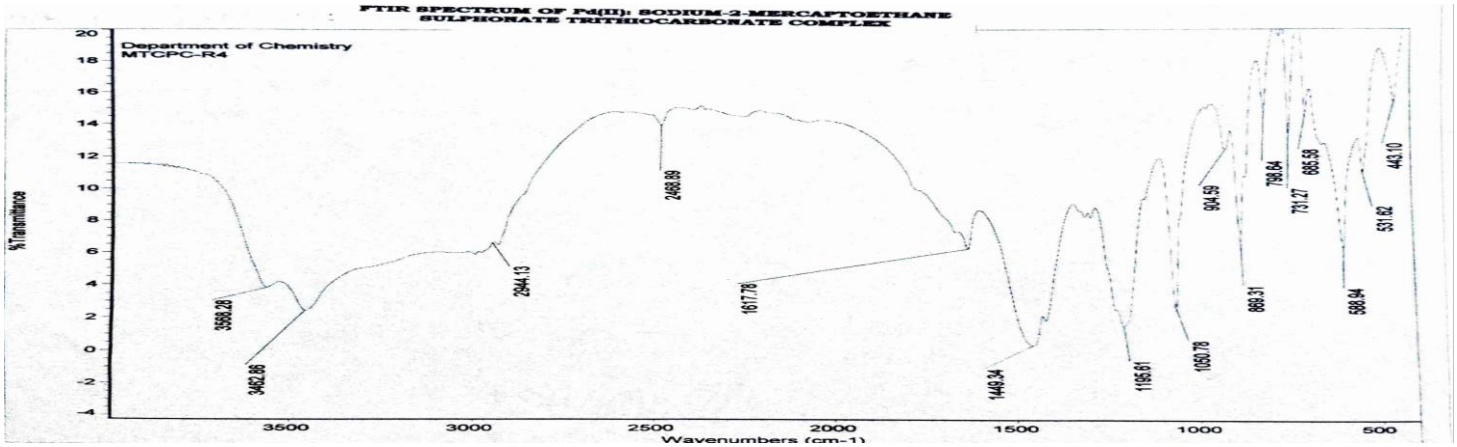


Figure 2: FTIR spectra of MTTCPD complex

The 1H NMR spectrum of the 1:2 complex of Palladium (II) and MTTC at 299.9MHz was recorded in D_2O. MTTC exhibit an NMR signal at 2.77ppm by$S\text{-}CH_2$ protons [26] which shows a downfield shift MTTCPD complex to 3.0 ppm. The 2.6 ppm chemical shift is linked to the sulphide group of trithiocarbonate appeared completely in its palladium(II) complex verifying the binding of a sulphur atom to the palladium (II) of trithiocarbonate group [27] as can be seen in figure 3.

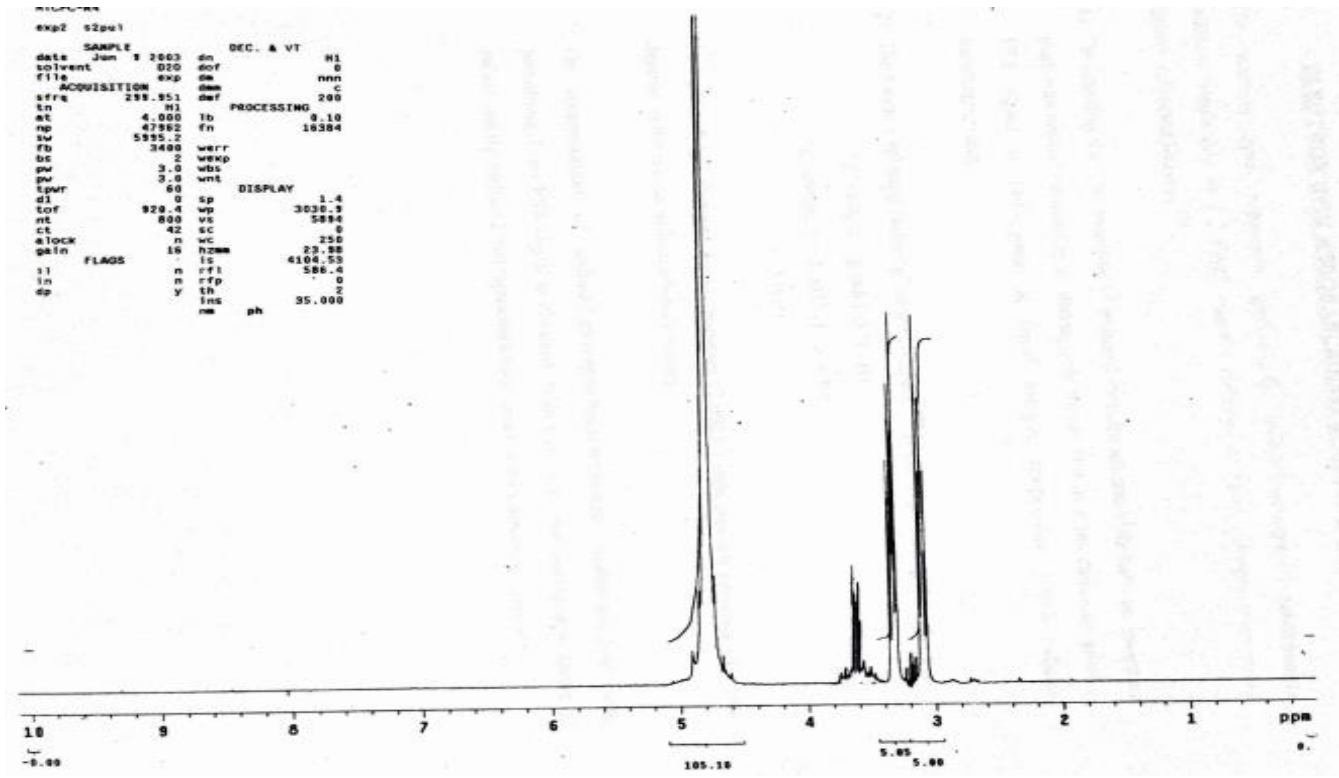


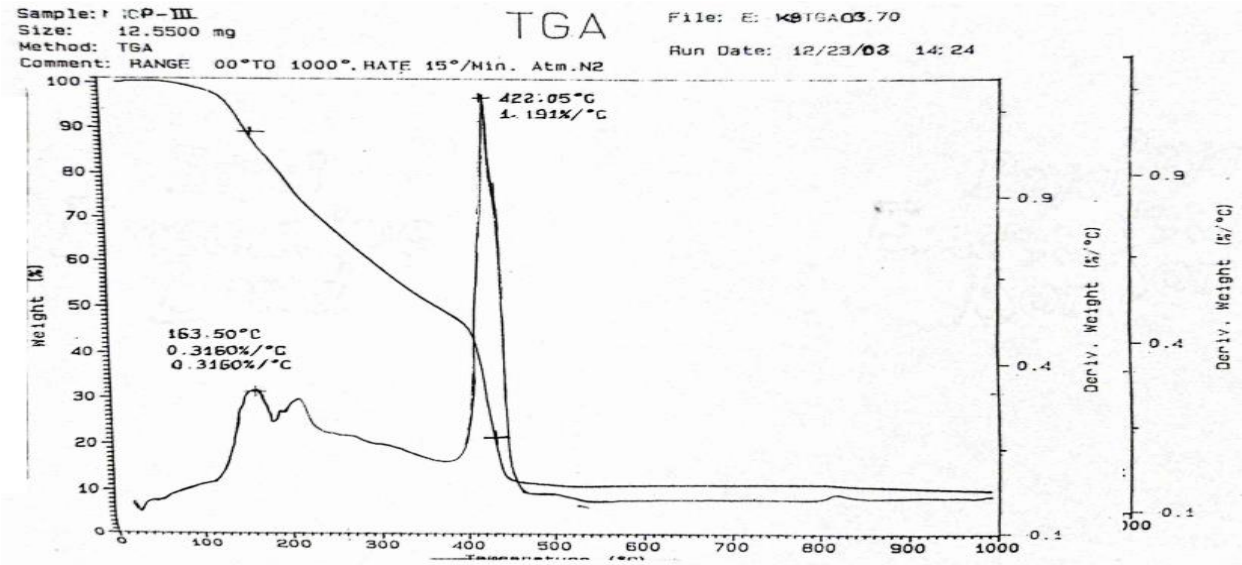
Figure 3: 1H NMR spectra of MTTCPD complex

At liquid nitrogen temperature, the electron spin resonance spectra of MTTC and its 1:2 Pd (II) complex were recorded [28]. Mesna's diamagnetic nature is confirmed by the absence of a resonance peak in its ESR spectra. But its trithiocarbonate gives an ESR signal at 1400 gauss at liquid nitrogen temperature, which indicates paramagnetism. The Lande's splitting factor "g" of the complex as calculated is 2.0023 indicating the presence of a free electron in the MTTC moiety whereas the MTTCPD complex exhibits no ESR signal which confirms its diamagnetic nature.

Laser Raman Spectra of trithiocarbonate of sodium2-mercaptoethanesulphonate and its 1:2 Pd(II) complex were recorded in the range 50-4000cm^{-1} using argon-ion laser line at 488nm as exciting radiation. A Raman Band in the spectrum of trithiocarbonate of sodium 2-mercaptoethane sulphonate at 680 cm^{-1} assigned to the C-S stretch is diminished and shifted to 675.5 cm^{-1} in the Pd (II) complex spectrum. Metal-sulphur bond gives a peak in the spectra of the Pd (II) complex of mesna TTC at 437.72 cm-1. A band at 744.8 cm^{-1} is associated with –C=S stretching frequency of the trithiocarbonate group disappears in the Pd (II) complex's Raman spectra.

Thermogravimetric analysis of MTTCPD complex conducted at a speed of 15 degrees per minute in a nitrogen atmosphere in the temperature range 0^{o}C to 1000^{0}C shows weight loss at 68^{o}C due to loss of lattice water molecules. Weight loss from 200^{o}C to 240^{o}C is because of the disappearance of coordinated water molecules from the complex. The rapture of the Pd-S bond is between 400^{o}C to 600^{o}C as can be seen in Figure 4.

Figure 4: TGA spectra of MTTCPD complex



The complex's thermal analysis (TGA) further validates the stoichiometry and the complex's geometry. Based on the aforementioned research, a complex structure has been suggested which can be seen in Figure 5.

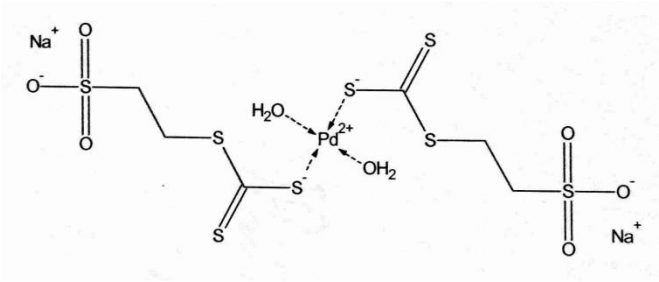


Figure 5: Proposed structure of MTTCPD complex

4. Conclusions

In the current study work an attempt was made to synthesize a trithiocarbonate derivative of commercial drug sample sodium 2-mercaptoethanesulfonate (brand name Mesna). The synthesized TTC derivative was used as a ligand to prepare the Pd (II) complex quantitatively. Calibration data for the MTTCPD complex was then determined. The complex's FTIR spectrum shows sulphur atom binding of trithiocarbonate ensemble with palladium (II). H^1 NMR studies of the complex in D_2O further confirm the involvement of the sulphur atom of the trithiocarbonate group in complexation with Pd (II). The absence of a signal in the complex's ESR spectrum shows the diamagnetic nature of the complex. Raman spectra of the complex show the participation of the trithiocarbonate group within bonding with the central metal atom. TGA study confirms the structure of the MTTCPD complex.

The synthesized ligand MTTC, according to the results binds to the S, S donor sites of trithiocarbonate in a bidentate manner with metal ions. The proposed method is simple, precise, less time-consuming and economical than earlier proposed methods for quantitative estimation of drug mesna in commercial samples with basic equipment.

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5. References

1. Bacon, J.R., Linge, K.L., Parrish, R.R. and Van Vaeck, L., *J. Analytical Atomic Spectrometry*, *21*(8), (2006)

2. Sharma, M., Koty, A., Srivastava, M. and Srivastava, A., J. *the Chinese Chemical Society*, *54*(6), (2007)

3. Stromgaard, K., Krogsgaard-Larsen, P. and Madsen, U. eds., Textbook *of drug design and discovery*. (2009)

4. Czarnek, K., Terpiłowska, S. and Siwicki, A.K., *Central European Journal of Immunology*, *40*(2), (2015)

5. Rizk, M., Taha, E.A., Mowaka, S. and Abdallah, Y.M., Chem *Sci Rev Lett*, *1*(3), (2012)

6. Shinde, G., Godage, R.K., Jadhav, R.S., Manoj, B. and Aniket, B., Research *J. Science and Technology*, *12*(1), (2020)

7. Howarth, A.J., Liu, Y., Li, P., Li, Z., Wang, T.C., Hupp, J.T. and Farha, O.K., *Nature Reviews Materials*, *1*(3), (2016)

8. Cui, Y., Li, B., He, H., Zhou, W., Chen, B. and Qian, G., *Accounts of chemical research*, *49*(3), (2016)

9. Vincent, S.G., Jyothi, R.K. and Joseph, J., *Materials Today: Proceedings*, *45*, (2021)

10. Kumar, D., *Materials Today: Proceedings*, *5*(1), (2018)

11. Zaki, M., Hairat, S. and Aazam, E.S., *RSC advances*, *9*(6), (2019)

12. Haggag, R.S., Gawad, D.A., Belal, S.F. and Elbardisy, H.M., *Bulletin of Faculty of Pharmacy, Cairo University*, *54*(1), (2016)

13. Ravichandran, R., Rajendran, M. and Devapiriam, D., *Food Chemistry*, *146*, (2014)

14. Shrivastava, R., Meena, M. and Nagar, H., *Advanced Science, Engineering and Medicine*, *11*(1-2), (2019)

15. Pokharna, S., Gupta, K.D., Mahla, R. and Kirpalani, C., Asian *Journal of Chemistry*, *16*(3), (2004)

16. Chauhan, A.B. and Patel, D.B., J. *pharmaceutical science and bioscientific research*, *2*(2), (2012)

17. Silva, L.M.D., Almeida, A.E.D. and Salgado, H.R.N., Adv. *Anal Chem*, *2*, (2012)

18. Cartwright, A.C., The British pharmacopoeia, 1864 to 2014,(2016)

19. Farid, N.F. and Abdelwahab, N.S. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, *145*, (2015)

20. Khan, N., Abdelhamid, H.N., Yan, J.Y., Chung, T. and Wu, H.F., Analytical Chemistry Research. (2015)

21. K. M. Reddy, K. Suvardhan, K. Suresh, S. Prabahar, P. Chiranjeevi, University of Madras and Faculty of Environmental Studies, 410-416,(2003)

22. Farid, N.F. and Abdelwahab, N.S., *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, *145*, (2015)

23. Tzanavaras, P.D. and Themelis, D.G., *J. pharmaceutical and biomedical analysis*, *43*(5), (2007)

24. Smith, A.A., Manavalan, R., Kannan, K. and Rajendiran, N., *Oriental Journal of Chemistry*, *24*(1), (2008)

25. S Mishra AP., Srivastava V.; J.Indian Chem. Soc.; 74. (1997).

26. Putharaya KH., Srivastava TS. Amonkar AJ., Adwankar MK., Chitnis MP, J.Inorg. Biochem, 25, (1985).

27. Kemp.W.; Org.Spectro. IIIrd ed., pub E.L.B.S. with Mc Millan, (1991).

28.pinner .E.; J. Chem. Phy.; 1237,(1969).