Earthline Journal of Chemical Sciences
E-ISSN: 2581-9003; CODEN: EJCSB4
Volume 11, Number 4, 2024, Pages 593-598
https://doi.org/10.34198/ejcs.11424.593598

On the interaction of uric acid with ammonium molybdate in acidic medium

Francisco Sánchez-Viesca*

Organic Chemistry Department, Faculty of Chemistry, National Autonomous University of Mexico, Mexico City (CDMX), Mexico
e-mail: franviesca@yahoo.com

Reina Gómez

Organic Chemistry Department, Faculty of Chemistry, National Autonomous University of Mexico, Mexico City (CDMX), Mexico
e-mail: reinagomezg@yahoo.com.mx

Abstract

This communication is a theoretical organic chemistry study on the interaction of uric acid with ammonium molybdate in acidic medium (Gigli test for uric acid). Colour tests give rapid, visible, results. However, it is interesting know what is happening in the test tube at molecular level. In the present paper we describe the reaction route of the above mentioned assay. Each step is fully commented and the electron flow is also given. The key stages are: addition of molybdic acid to the C-C double bond, acidolysis of the organometallic ester with reduction to molybdenum (IV) and epoxide formation (oxidation step). Ring opening of the oxirane and reaction with water. A glycol is formed followed by opening of the five-member ring giving a carbonyl and an ureido chain. Finally, elimination of urea gives rise to 2,4,5,6-tetraoxo-hexahydropyrimidine (alloxan) which is hydrated. The blue colour observed (molybdenum blue) is a mixture of several oxides.

1. Introduction

The medical importance of uric acid is well-known. Hyperuricemia produces gout and kidney stones. That is why uric acid has attracted the attention of chemists and

---

Received: October 3, 2024; Accepted: October 16, 2024; Published: October 20, 2024

Keywords and phrases: acidolysis; addition to double bind; alloxan; carbinolamine; epoxide formation; glycol; molybdenum blue.

*Corresponding author

physicians in order to identify and determine uric acid. Several colour tests for uric acid have been developed. These experimental assays are very useful, but it is interesting know what is happening at molecular level in the test tube.

In the present communication we describe the chemical route of the interaction of sodium urate with ammonium molybdate in acidic medium. Each step is fully commented and the electron flow is given. This paper is a follow up of our studies on reaction mechanism, [1-5].

2. Antecedents

The test under study is due to Dr. T. Gigli from Pavia, Italy. He published his article in the Chemist Newspaper in Köthen, Saxony, [6], and is recorded in the Pharmaceutical Central Portal of Dresden, [7]. It is registered in a book on chemical tests, [8].

The test is as follows: If a neutral 7.5% solution of ammonium molybdate is mixed with a solution of potassium urate and the mixture is acidified with sulphuric acid, and then after some minutes sodium hydrate solution is added until the reaction is alkaline, blue molybdenum oxide and a blue solution are obtained. Oxidizing agents such as chlorine or bromine, hypochlorite, hypobromite, potassium permanganate, decolorize the blue liquid. Then there must be a relationship between the uric acid present and the blue oxide formed, and there must also be a relationship between the amount of blue molybdenum oxide and that of the oxidizing agent necessary to decolorize the blue liquid. These reactions can be used for a volumetric determination of uric acid.

Some remarks about uric acid and ammonium molybdate. In 1882 the Ukrainian-Austrian chemist Ivan Horbaczewski first synthesized uric acid by melting urea with glycine, [9]. In 1962 Bills and coworkers published a complex new synthesis of uric acid, [10].

Molybdenum is an essential element that is present in enzymes like xanthine oxidase, sulfite oxidase and aldehyde oxidase, [11].

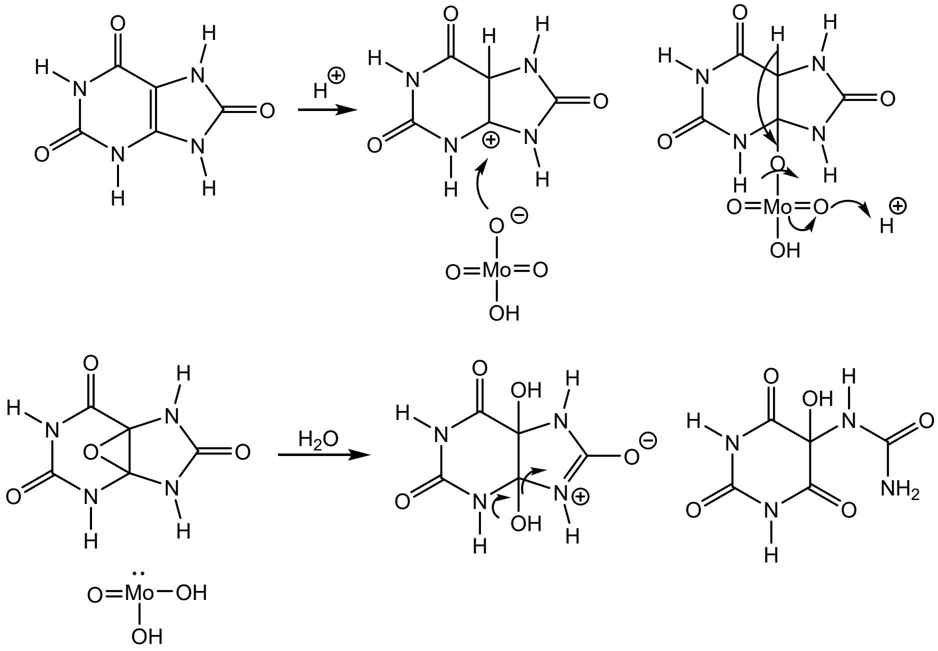
Ammonium molybdate, $H_8MoN_2O_4$, is a white to greenish-yellow solid. Sink sand mixes with water. It exists in several hydrate forms (di-, tetra-, hexa-, and heptahydrate). It is intravenously administered as an additive to solutions for total parental nutrition, [12]. IUPAC nomenclature is Ammonium Dioxido(Dioxo)Molybdenum Hydrate (2:1:4), [13].

Ammonium molybdate tetrahydrate is a plant micronutrient that has been shown to aid in the conversion of nitrogen to ammonium, [14]. This compound is also used as analgesic [15], and in the oxidation of sulfides to sulfonyls [16]. It improves chlorophyll synthesis [17].

There is an interesting review (experimental) about the reduction of ammonium molybdate in acid solution [18].

3. Discussion

The first reactions with sulphuric acid are formation of uric acid and molybdic acid from the salts employed. There is addition of molybdic acid to the C-C double bond in uric acid. The first step is protonation at C-5, leaving a carbonium ion far from the carbonyl group at C-6. The carbocation is neutralized by a molybdate anion. Acidolysis of the organometallic ester occurs via protonation of a Mo-O double bond, originating molybdenum (IV) oxide hydrate (reduction step) with concomitant epoxide formation (oxidation step) by elimination of a hydrion from C-5. Figure 1.



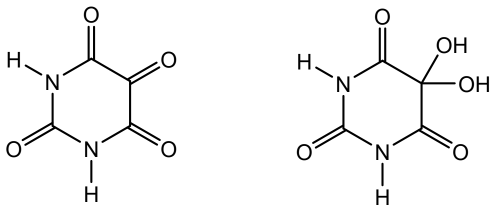


Figure 1. Route of the interaction of uric acid with ammonium molybdate in sulphuric acid

Ring opening of the oxirane by acid, followed by reaction with water, gives rise to a vicinal diol (glycol). Each hydroxyl is part of a pseudo carbinolamine. Ring opening of the 5-member ring is favored by the dipolar structure of the near amido group and the electrodotic [19-21] properties of the hydroxyl. A carbonyl group is formed in the 6-member ring, plus an ureido chain in the vicinal site. A second reaction eliminates a urea molecule, giving 2,4,5,6-tetraoxo-hexahydropyrimidine (alloxan) which is hydrated to alloxan monohydrate. This compound is formed in oxidations carried in acidic medium [22].

The blue compounds formed in this test are MoO_2 [23], Mo_2O_5 [24] and Mo_3O_8 [25].

4. Conclusion

The reaction route from uric acid to alloxan monohydrate has been established. It comprises addendum to double bond, acidolysis of organometallic ester, redox reactions giving molybdenum (IV) oxide hydrate, and an epoxide. Ring opening of the oxirane and reaction with water originates a glycol which is part of two pseudo carbinolamines. Rearrangement to carbonyl and ring opening gives rise to alloxan and elimination of a urea molecule. The blue colour observed in the test is due to three identified compounds.

5. Conflicts of Interest

There are no conflicts to declare.

6. Acknowledgement

Many thanks are given to Luz Clarita for support.

References

[1] Sánchez-Viesca, F., & Gómez, R. (2024). Mechanism of the interaction of alkaline tungstate with uric acid. *Journal of Chemical, Biological and Physical Sciences, 14*(4), 311-315. https://doi.org/10.24214/jcbps.A.14.4.31115

[2] Sánchez-Viesca, F., & Gómez, R. (2024). A complete and sustained organic/inorganic reaction mechanism of Baeyer's test. *Word Journal of Chemical and Pharmaceutical Sciences, 04*(02), 001-005. https://doi.org/10.53346/wjcps.2024.4.2.0023

[3] Sánchez-Viesca, F., & Gómez, R. (2024). On the mechanism of Siebold's test for morphine. *International Journal of Chemical and Pharmaceutical Research Updates, 02*(01), 010-013. https://doi.org/10.53430/ijcpru.2024.2.1.0021

[4] Sánchez-Viesca, F., & Gómez, R. (2023). The mechanism of Frabot test for uric acid. *Earthline Journal of Chemical Sciences, 10*(1), 125-130. https://doi.org/10.34198/ejcs.10123.125130

[5] Sánchez-Viesca, F., & Gómez, R. (2023). The mechanism of Hager's test for glucose. *International Journal of Advances in Chemical Research, 5*(1), 47-49. https://doi.org/10.33545/26646781.2023.v5.i1a.143

[6] Gigli, T. (1898). Uebereine Reaction der Harnsäure und eine volumetrische Bestimmungsmethode derselbe. *Chemiker Zeitung, 22*(34), 330-331. via Internet Archive: https://archive.org/details/chemikerzeitung2211unse/page/330/mode/1up

[7] Gigli, T. (1898). Reaction auf Harnsäure. *Pharmazeutische Zentralhalle für Deutschland, Dresden*, 39, 558.

[8] Merck, E. (1903). *Merck´s Reagentien Verzeichnis* (p. 50). Darmstadt: Springer. https://doi.org/10.1007/978-3-642-99730-3

[9] Horbaczewski, I. (1882). Synthese der Harnsäure. *Monatsheftefüir Chemie*, *3*, 796-797. https://doi.org/10.1007-BF01516847

[10] Bills, C.W., Gebura, S.E., Meek, J.S., & Sweeting, O.J. (1962). New synthesis of uric acid and 1,7-dimethyluric acid. *Journal of Organic Chemistry, 27*(12), 4633-4635. https://doi.org/10.1021/jo01059a501

[11] Molybdenum. https://go.drugbank.com>ammonium-molybdate

[12] Ammonium molybdate, description. https://pubchem.ncbi.nlm.nih.gov>ammonium-molybdate

[13] Ammonium molybdate, IUPAC nomenclature. https://cymitquimica.com>ammonium-monibdate-tetrahydrate

[14] Ammonium molybdate, conversion of nitrogen into ammonium. https://phytotechlab.com/ammonium-molybdate-tetrahydrate.html

[15] Ammonium molybdate, as analgesic. https://ww.mpbio.com>0215249780-ammonium-molybdate

[16] Ammonium molybdate, as oxidizer. https://www.scbt.com>ammonium-molybdate

[17] Ammonium molybdate, as fertilizer. https://www.katyayaniorganis.com>ammonium-molybdate

[18] Miller, C.W., & Taylor, A.E. (1914). On reduction of ammonium molybdate in acid solution. *Journal of Biological Chemistry, 17*(4), 531-535. https://doi.org/10.1016/S0021/9258(18)88396-X

[19] Hall, N.F. (1941). Electrophiles and electrodotes. *Journal of the American Chemical Society, 63*(3), 883. https://doi.org/10.1021/ja01848a517

[20] *Merriam-Webster Dictionary*, electrodotic, meaning. https://www.merriam-webster.com>electrodotic

[21] *Academic Dictionaries and Encyclopedias*, electrodotic, etymology. https://useful_english.en-academic.com>electrodotic

[22] Giral, F., & Rojahn, C.A. (1956). *Productos químicos y farmacéuticos* (Vol. 3, p. 1915). México: Atlante.

[23] Molybdenum (IV) oxide. https://datasheets.scbt.com/sc-235882.pdf

[24] Dimolybdenum pentoxide. https://www.webelements.com/compounds/molybdenum/dimolydenum_pentaoxide.html

[25] Pesez, M., & Poirier, P. (1954). *Méthodes et réactions de l´analyse organique* (Vol. 3, p. 9), Paris: Masson.