International Journal of Scholarly Research in
Chemistry and Pharmacy
Journal homepage: https://srrjournals.com/ijsrcp/
ISSN: 2961-3302 (Online)

(RESEARCH ARTICLE)

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On the interaction of glucose with ammonium molybdate (Hager-Gawalowsky test)

Francisco Sánchez-Viesca * and Reina Gómez Gómez

Organic Chemistry Department, Faculty of Chemistry, National Autonomous University of Mexico, Mexico City (CDMX), Mexico.

International Journal of Scholarly Research in Chemistry and Pharmacy, 2024, 04(02), 001–003

Publication history: Received on 05 September 2024; revised on 15 October 2024; accepted on 17 October 2024

Article DOI: https://doi.org/10.56781/ijsrcp.2024.4.2.0034

Abstract

Glucose is an Analyte. Thus, several tests for its detection in urine have been developed. In the present communication the reaction route of the Hager-Gawalowsky test for glucose is provided. Each step is fully commented and the electron flow is also given. The test is based on the interaction of glucose with ammonium molybdate in neutral medium, a blue colour is produced on heating. The active hydrogen in glucose is removed by the inorganic anion, and the resulting enolate from an enediol reacts with the mono-anion just formed. A hydroxylate is eliminated via open-close of a Mo-O double bond. Hydrion switch forms a second enolate that produces a concerted mechanism affording 2-ketoglucose and molybdenum dioxide by a redox reaction.

Keywords: Ammonium molybdate; Hager-Gawalowsky test; 2-Ketoglucose; Molybdenum blue; Molybdenum dioxide; Reactive intermediates; Redox reaction

1 Introduction

The medical importance of glucose level in the organism is well-known. High levels of this Analyte are symptoms of Diabetes mellitus, and they must be controlled. That's why detection followed by determination of glucose either in urine or in blood are so important.

In the present communication the reaction route of the Hager-Gawalowsky test for glucose is provided. Each step is fully commented and the electron flow is also given. This article is a follow up of our studies on reaction mechanism, [1-5].

2 Study Method and Process

This is an Organic Chemistry Theoretical Study. It is based on the chemical deportment of reagent and substrate. All is in accordance with the reaction medium and the catalyst present. The several steps leading to the final product have been fully commented and the reaction mechanism is given too.

2.1 Antecedents

The test under study is due to Herman Hager (1816-1897) and the Polish chemist Gawalowsky, [6, 7]. The test is as follows: an aqueous solution of ammonium molybdate in contact with glucose gives a blue colour after heating.

Some remarks about the reagent. Ammonium molybdate, $(NH_4)_2MoO_4$ is a white to greenish-yellow solid. It sinks and mixes with water and exists in several hydrate forms (di-, tetra-, hexa- and heptahydrate), [8]. The IUPAC nomenclature is Ammonium dioxido(dioxo)molybdenum hydrate (2:1:4), [9].

* Corresponding author: Francisco Sánchez-Viesca

Ammonium molybdate tetrahydrate is a plant micronutrient that has been shown to aid in the conversion of nitrogen to ammonium, [10]. This compound is also used in the oxidation of sulphides to sulphonyls [11], and improves chlorophyl synthesis, [12].

There is an interesting review (experimental) about the reduction of ammonium molybdate in acid solution, [13].

3 Discussion

Being glucose a carbon acid, the hydrogen at C-2 is abstracted by the molybdate anion, giving the monoanion of an enediol. Figure 1. The new two species react with each other. The anion of a molybdic ester is formed via polarization of a Mo-O double bond

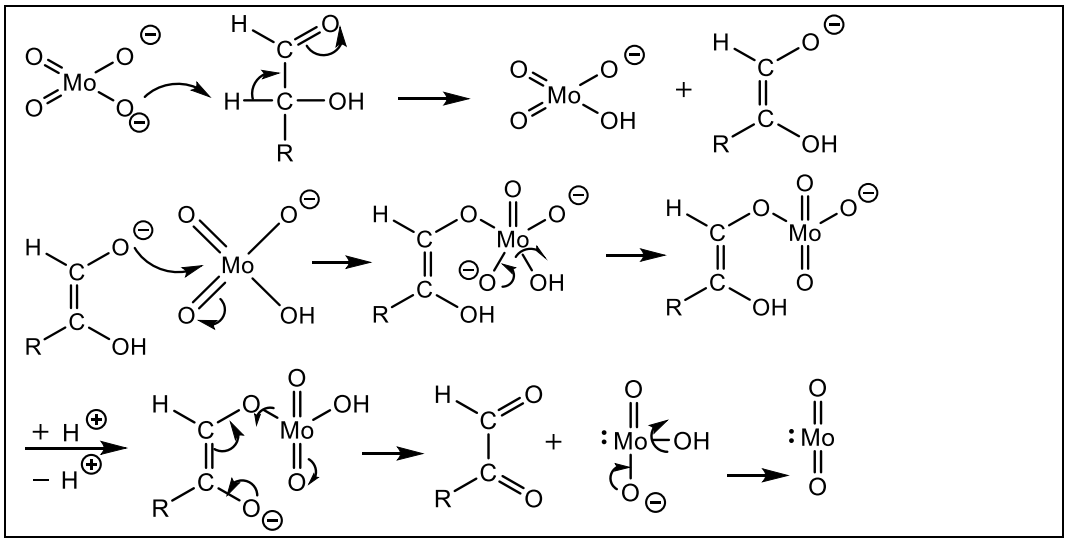

Figure 1 Reaction route of the interaction of glucose with ammonium molybdate

and elimination of a hydroxyl anion. Proton interchange gives an electrodotic enolate [14, 15], that originates a concerted mechanism involving four electron shifts. Finally, there is hydroxyl elimination from the detached Molybdenum (IV) intermediate and blue molybdenum dioxide [16] is formed (reduction product), along with 2-ketoglucose, glucosone (oxidation product).

Two other blue compounds are formed: Mo_2O_5 [17], and Mo_3O_8 [18]. Both compounds derive from MoO_2.

4 Conclusion

The reaction route of the interaction of glucose with ammonium molybdate has been given. The active hydrogen in glucose is captured by the molybdate anion, and an enolate results. This reacts with the molybdate mono-anion, and hydroxylate loss affords an organometallic molybdate ester. Hydrion switch favours a concerted mechanism that gives 2-ketoglucose and molybdenum dioxide.

Compliance with ethical standards

Acknowledgments

Thanks are given to Luz Clarita for support.

Disclosure of conflict of interest

There is no conflict of interest to declare.

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