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Ferric Sulfate: An Emerging Catalytic Reagent for The High Yield Synthesis of Thiourea

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Abstract

Thiourea is a rapidly growing chemical compound which has never seen a drop in the global demand from the last five decades. In this modern era, the thiourea based compounds and products are flourishing like everything. The present syntheses of symmetrical and asymmetrical thioureas by a one-pot reaction of the appropriate amine (diethylamine), carbondisulfide (CS_2), and an oxidant, i.e., ferric sulfate, was investigated in this work. The mechanism of thiourea synthesis was established based on the identification of the reaction intermediates. The research will surely influence the worldwide researchers and industry personnel for the adaption of this unique emerging method for producing thiourea.

Keywords

Ferric Sulfate, Thiourea, Catalyst, Synthesis, Yield, Mechanism.

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1. INTRODUCTION

Thiourea is a rapidly growing chemical compound which has never seen a drop in the global demand from the last five decades. A close analog of urea, finds ample opportunities in modern pharmaceuticals, chemical products development and cosmetics. In this modern era, the thiourea based compounds and products are flourishing like everything [1]. The thiourea compounds first received limelight two centuries back when the foundation stone towards the formation of novel components was kept and the development of thiourea moieties with antimicrobial properties were at highest booming stage [2].

A few examples can be courted which demonstrates that the starting material has immense importance and play imperative role. The Thiourea reduces peroxides to the corresponding diols. Thiourea is commonly employed as a source of sulfide for converting alkyl halides to thiols. Substituted thioureas are useful catalysts for organic synthesis and the phenomenon is called thiourea organocatalysis [3]. Thiourea is used as an auxiliary agent in diazo paper, light-sensitive photocopy paper, and almost all other types of copy paper. Other industrial uses of thiourea include production of flame retardant resins and vulcanization accelerators [4]. Thioureas are also used a building blocks for the synthesis of pyrimidine derivatives and several pharmaceutically important medicines such as thiobarbiturates are produced from this small ligand [5].

The proposed method is characterized by operational simplicity and yields of the obtained products, recycling of the solvents, and absence of dangerous by-products in the effluent water. There are numerous operationally simple catalytic synthesis methods performed in water as the reaction medium [6]. The present syntheses of symmetrical and asymmetrical thioureas by a one-pot reaction of the appropriate amine (diethylamine), carbondisulfide (CS_2) and an oxidant, i.e., ferric sulfate, was investigated in this work. The mechanism of thiourea synthesis was established based on the identification of the reaction intermediates.

2. MATERIALS AND METHODS

2.1. Chemicals

The chemicals reagents (diethylamine, carbon disulphide, ferric sulfate, and ethylamine) employed in the study were of analytical grade and exclusively procured from HiMedia Chemicals Ltd., Mumbai. Double distilled water (Borosil®) was utilized during the study.

2.2. Instrumentation

The progress of the chemical reaction was monitored by Merck® pre-coated silica Gel-G thin layer chromatography plates. Spectroscopic characterization was performed on KBr discs based Fourier-transformed infrared (FT-IR) (IRAffinity-1 instrument), proton (^{1}H)-NMR at 300 MHz (Bruker spectrospin NMR DPX-300 instrument) through the internal standard tetramethylsilane, and the mass spectra was recorded on a JEOL-JMS-DX 303 instrument.

2.3. Synthetic protocol

To a 500 mL three necked round bottom flask equipped with a reflux condenser, dropping funnel, thermometer and a magnetic stirrer were added 110 mL of water and 17 mL (0.16 mol) of 98% diethylamine **(1)**. Subsequently, 10.2 mL (0.16 mol) of 98% carbon disulfide **(2)** (water was added as a top layer to prevent pressure development above the carbon disulfide in the dropping funnel) was added over 1 hr under efficient stirring and maintaining the low temperature of the reaction mixture (**Figure 1**). The oxidation process was performed by the addition of 23.2 mL (0.09 mol; 13.2%) of ferric sulfate maintaining the reaction temperature in the range 40–45°C for 1 hr. The product **(3)** gets formed as suspended during the addition of the ferric sulfate solution. Afterwards, 12.55 mL (0.16 mol) of 68% ethylamine and 23.2 mL (0.09 mol; 13.2%) of ferric sulfate was added into reaction mixture and the temperature kept in the range 40–45°C for an additional 1 hr. The process yielded suspended thiourea product **(3)**, which was subsequently separated by filtration, washed thoroughly with the cold water, dried in air and suitably recrystallized.

3. RESULTS AND DISCUSSION

3.1. Characteristics of thiourea

The spectroscopic analyses of the final product **(3)** demonstrated a distinct disparity from the diethylamine **(1)**. The FT-IR spectra of thiourea distinctly depicted the absence of –NH group which earlier appeared at 3032 cm^{-1}. In addition to it, the appearance of a C=S peak at 1189 cm^{-1} confirmed the formation of the compound. A similar absence of the proton peak in the amide (-NH) portion was perceived from the NMR studies for the destination compound in respect to the starting material which had a prominent amide proton at 2.31 ppm. The base peak (M^+ 188) in the mass spectra and the close agreement of the element ratio with that of the theoretical value further ascertained the formation of the product.

Color: brown color, m.p.: 84-86°C, Yield: 69.32%; FTIR (KBr) υ (cm^{-1}): 1477 ($-CH_3$), 1451 ($-CH_2$), 1354 (C-N, stretching), 1189 (C=S); ^{1}H-NMR (δ, ppm, $CDCl_3$): 4.54 (2H, CH_2), 1.28 (3H, CH_3); MS: M^+ 188. Anal. Calcd. for $C_9H_{20}N_2S$: C, 57.40; H, 10.70 N, 14.87. Found: C, 56.03; H, 10.11; N, 14.18.

3.2. Proposed mechanism

In this novel method, the secondary amines are converted into thiourea by taking equimolar concentration of amides **(A)** with carbon disulfide **(B)** to form the disubstituted-ammonium salt of (substituted) carbodithioic acid **(C)** which on further

reaction in the molar ratio of 2:1 produced disubstituted-ammonium salt of (substituted) carbodithioic acid **(D)**. Further oxidation by ferric sulfate **(E)** resulted in the formation of an intermediate conjugated thiourea compound **(F)**, which on further reaction with the secondary amide **(A)** leads to the formation of thiourea **(G)**.

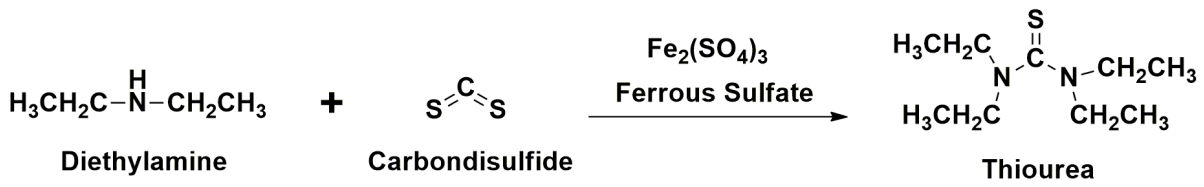

Figure 1. Formation of thiourea from diethylamine by using ferric sulfate.

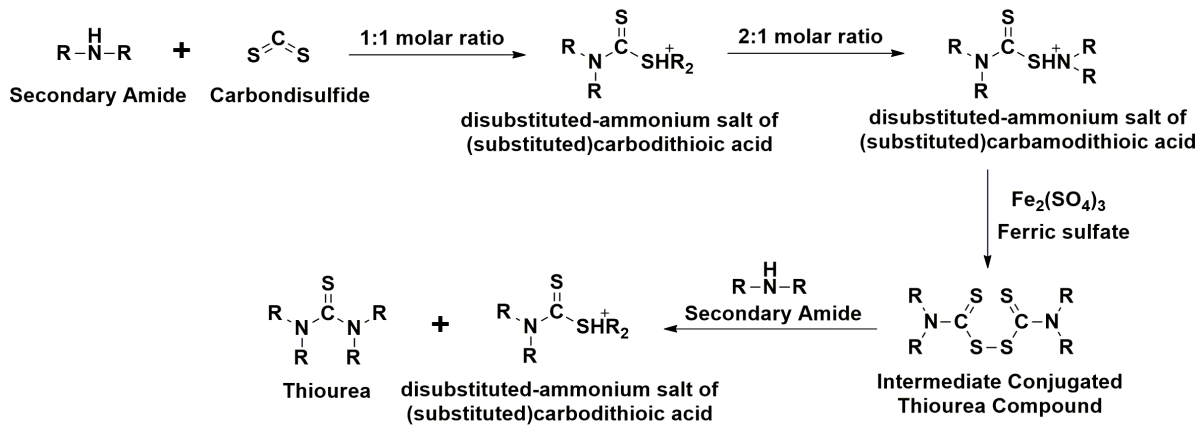

Figure 2. The proposed mechanism for the synthesis of thiourea from diethylamine by using ferric sulfate.

4. CONCLUSION

The current ferric sulfate based very high yield method opened opportunities in meeting the globally rising industrial demands of thiourea from secondary amides with better scalability. The study proved to be a superior option than the existing prevailing chemically oxidative methods such as hydrogen peroxide induced oxidation etc. which often give less uniform content along with lower yield. The research will surely influence the worldwide researchers and industry personnel for the adaption of this unique emerging method for producing thiourea.

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