



Synthesis of Blue Pigment from Copper

M. K. Afreza^{1*}, A. N. Sari¹, S. J. Sundoro¹

1. Chemical Engineering Department, Vocational School, Universitas Sebelas Maret, Jl. Kol. Sutarto 150K Jebres, Surakarta 57126, Indonesia

* Corresponding author: eza.8@student.uns.ac.id

doi: <https://doi.org/10.20961/esta.v4i1.109667>

Received: 08-10-2025; Revised: 30-03-2026; Accepted: 31-03-2026; Published: 01-04-2026

ABSTRACT: Blue inorganic pigments are essential materials in various industries, including coatings, ceramics, and plastics. This research investigates the synthesis of blue pigment, specifically copper sulfate pentahydrate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$), derived from recycled copper scrap through a hydrometallurgical process. The synthesis involves two primary stages: the dissolution of copper coils in HNO_3 and the subsequent reaction with H_2SO_4 to induce crystallization. Three experimental trials were conducted to evaluate the consistency of the process and the resulting mass yield. The results showed that the weight of the recovered blue pigment ranged from 6.24 g to 8.27 g. This corresponds to a mass yield percentage between 39.10 % and 51.82 % relative to the starting material. Analysis of the process parameters reveals that the concentration of the acid solvents and the crystallization conditions are critical in determining the final product's crystalline quality and color intensity. This study provides a sustainable approach for converting metal waste into value-added coloring agents with potential industrial applicability.

Keywords: Blue Pigment, Copper Scrap, Hydrometallurgy, Mass Yield.

1. INTRODUCTION

The rapid development of various industrial sectors in Indonesia has significantly increased the demand for high-quality raw materials, including coloring agents and chemical precursors [1]. Among these materials, copper sulfate pentahydrate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$) crystals have emerged as a vital component in numerous applications, ranging from agriculture and electroplating to the production of high-grade inorganic pigments [2]. As the industry seeks more sustainable practices, the synthesis of

these crystals from secondary resources has become a strategic priority.

Pigments are natural or synthetic substances that produce color through the selective absorption of light, exhibiting unique optical properties that are essential for the aesthetics and functionality of industrial products [3]. Blue inorganic pigments, in particular, are highly sought after due to their vibrant hues and chemical stability. In many cases, these pigments are synthesized from transition metals, where the specific

crystalline structure determines the final color intensity and durability [4, 5].

Copper (Cu) is a versatile transition metal widely used in electrical and manufacturing industries, leading to the generation of significant amounts of copper scrap, such as used coils and wires [6]. If not managed properly, metal waste can lead to environmental degradation; however, it also represents a valuable secondary source for metal recovery [7]. Converting copper waste into value-added products like blue pigments aligns with the principles of green chemistry and circular economy [8].

The extraction and conversion of metals from scrap are typically performed through hydrometallurgical processes. Hydrometallurgy is a metal recovery technique carried out at relatively low temperatures using chemical leaching solutions [9, 10]. This method is preferred over pyrometallurgy due to its lower energy consumption, reduced gaseous emissions, and high selectivity in recovering pure metal compounds from complex waste streams [11].

In the synthesis of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ crystals, the process involves the leaching of copper scrap using a combination of strong acids. Nitric acid (HNO_3) acts as a powerful oxidizing solvent to dissolve the metallic copper, while sulfuric acid (H_2SO_4) provides the sulfate ions necessary for crystal formation [12]. The reaction sequence must be carefully controlled to ensure the complete dissolution of the precursor and the subsequent growth of high-purity crystals during the crystallization stage [13].

Despite its potential, the efficiency of converting copper coils into copper sulfate pentahydrate or blue pigments through this hydrometallurgical route requires systematic evaluation. Factors such as solvent concentration, reaction time, and temperature stability are

decisive in determining the final yield and product quality [14]. Previous studies have explored various leaching agents, but the optimization of the HNO_3 - H_2SO_4 system for scrap copper remains a critical area of investigation [15, 16].

This research specifically aims to study the synthesis of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ crystals from scrap copper coils. The study focuses on the stages of dissolution, reaction, and crystallization to obtain high-quality blue pigments. By evaluating multiple experimental trials, this work provides insights into the mass yield and consistency of the recovery process, contributing to a more sustainable supply chain for inorganic coloring agents in the industrial sector.

2. MATERIALS AND METHODS

2.1 Materials

The primary raw material used in this study was recycled copper scrap obtained from used electrical coils. The chemical reagents employed for the synthesis included analytical grade nitric acid (HNO_3) as the oxidizing solvent and sulfuric acid (H_2SO_4) as the sulfate source. Distilled water was used for all solution preparations and washing procedures.

The experimental apparatus consisted of a magnetic stirrer with a heating plate, analytical balance, digital thermometer, and various laboratory glassware, including beakers (250 mL and 500 mL), glass funnels, and volumetric flasks. Filtration was performed using analytical-grade filter paper, and the final drying process was carried out in a laboratory oven.

2.2 Methodology

The synthesis of blue pigment crystals followed a three-stage hydrometallurgical route: leaching, reaction, and crystallization.

2.2.1. Leaching Process

The copper scrap was initially cleaned to remove surface contaminants. A specified mass of copper (15.96 g) was placed in a beaker and dissolved using a concentrated HNO_3 solution. This leaching stage was conducted under constant stirring until the copper was completely oxidized and dissolved, resulting in a copper nitrate solution.

2.2.2. Reaction and Synthesis

Following the dissolution, a calculated volume of H_2SO_4 was introduced into the solution. The mixture was heated and stirred at a controlled temperature to facilitate the reaction between the dissolved copper ions and the sulfate groups. This stage is critical for the formation of the copper sulfate precursor required for the blue pigment.

2.2.3. Reaction and Synthesis

The resulting solution was then subjected to a controlled cooling and evaporation process to induce the formation of blue crystals. The crystals were separated from the mother liquor via filtration. The recovered crystals were washed with distilled water to remove residual acids and impurities. Finally, the product was dried in an oven at $100\text{ }^\circ\text{C}$ until a constant weight was achieved. The experiment was repeated three times to ensure the reproducibility of the mass yield.

3. RESULTS AND DISCUSSION

The synthesis of blue pigment crystals from recycled copper scrap was evaluated through three independent experimental trials. The efficiency of the hydrometallurgical conversion was measured based on the final weight of the recovered pigment relative to the initial precursor mass (15.96 g). The experimental data, focusing on the pigment mass and the corrected mass yield, is summarized in Table 1.

Table 1. Mass yield and recovery efficiency of synthesized copper(II) sulfate pentahydrate

Sample	Pigment Mass (grams)	Yield (%)
1	6.24	39.10
2	8.27	51.82
3	7.37	46.18
Average	7.29	45.70

The results indicate an average mass yield of 45.70 %, with Sample 2 achieving the highest yield of 51.82 %. The variations in yield across the samples are likely influenced by the efficiency of the leaching stage using HNO_3 . In the hydrometallurgical route, the complete dissolution of metallic copper into Cu^{2+} ions is highly dependent on the contact time and the stirring intensity. This stirring process, which is essential for ensuring a homogeneous reaction between the copper nitrate solution and the sulfate sources, is visually represented in Figure 1. Consistent stirring facilitates the uniform precipitation of the pigment particles, preventing localized concentration gradients that could hinder crystal growth.



Figure 1. Stirring the solution

The formation of blue pigment is highly sensitive to operational factors, most notably the pH and reaction temperature. During the synthesis, the pH was meticulously maintained between 2 and 3

using a 4M NaOH solution to provide optimal conditions for the formation of the copper-based precipitate. Maintaining an acidic environment is crucial to preventing the premature formation of copper hydroxides, which would compromise the purity and distinctive blue hue of the final product.

Furthermore, the reaction temperature plays a pivotal role in crystalline growth. A constant temperature of 60 °C was employed to accelerate the reaction rate while ensuring the stability of the copper sulfate pentahydrate phase. As reported in previous studies on metal oxide synthesis, temperature stability is directly linked to the reproducibility of the product's physical properties, such as particle size distribution and color intensity.

The final product obtained after drying at 100 °C and grinding is a fine blue powder. The physical appearance of the synthesized pigment is shown in Figure 2, exhibiting the characteristic vibrant blue hue associated with copper-based inorganic pigments. The grinding process is vital to achieve a uniform particle size, which directly impacts the pigment's hiding power and its effectiveness in industrial applications.



Figure 1. Copper sulfate pentahydrate

From an industrial perspective, recovering copper from recycled scrap to produce value-added pigments aligns with the principles of circular economy. This

copper sulfate pentahydrate-type blue pigment offers a sustainable alternative for the paint and ceramic industries, where chemical resistance and thermal stability are paramount. The ability to produce consistent yields through this hydrometallurgical route highlights its potential for scalable industrial production.

4. CONCLUSION

The synthesis of blue inorganic pigment, specifically copper sulfate pentahydrate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$), was successfully achieved using a hydrometallurgical route starting from recycled copper scrap. By employing a controlled leaching process with HNO_3 followed by a reaction with H_2SO_4 , the study demonstrated an effective method for converting industrial metal waste into a value-added coloring agent.

The experimental results revealed that the process achieved a consistent production of blue crystals, with a mass yield ranging from 39.10 % to 51.82 %, and an average yield of 45.70 %. These findings, as summarized in Table 1, indicate that the efficiency of the synthesis is highly dependent on the precision of pH control (maintained at 2–3) and the consistency of the stirring process, which ensures a homogeneous reaction environment as depicted in Figure 1.

Furthermore, the physical characteristics of the final product, shown in Figure 2, confirm the formation of high-quality blue pigment suitable for industrial applications. This research highlights the potential of using secondary resources to support a circular economy in the chemical industry. Future studies should focus on optimizing acid concentrations and cooling rates to further enhance the mass yield and crystalline purity for large-scale production.

ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to the Diploma III Study Program in Chemical Engineering, Vocational School, Universitas Sebelas Maret, for providing the laboratory facilities and the necessary equipment to conduct this research on metal recovery. We also extend our deepest appreciation to Mr. Cornelius Satria Yudha, S.T., M.T., and Ms. Himmah Sekar Eka Ayu Gustiana, S.T., M.Eng., for their constant support, technical guidance, and insightful discussions during the experimental

REFERENCES

- [1] M. Zulfikar, E. Kusdiantini, and S. Nurjanah, "Identification Pigment Types and Potency Tests Antioxidants Bacterial Pigment Extract *Rhodococcus sp* Isolation Results from Sediment Hot Springs Building Songo," *J. Biol.*, vol. 6, no. 4, pp. 106-114, 2019.
- [2] G. Buxbaum and G. Pfaff, *Industrial Inorganic Pigments*. Weinheim: Wiley-VCH, 2005.
- [3] M. G. S. J. de Castro and S. J. L. Ribeiro, "Inorganic Pigments: A Review," *J. Braz. Chem. Soc.*, vol. 21, no. 12, pp. 2215-2230, 2010.
- [4] H. Smith, *Inorganic Pigments: Analysis and Industrial Applications*. New York: Scholastic Press, 2012.
- [5] M. A. R. Prambudi and Suprpto, "Determination of Copper (Cu) Content of Samples Mineral Rocks," *J. ITS Sci. Arts*, vol. 7, no. 2, pp. 2337-3520, 2019.
- [6] J. D. Lee, *Concise Inorganic Chemistry*, 5th ed. Oxford: Blackwell Science, 1996.
- [7] T. A. Rochman and F. Rofika, "Hydrometallurgical Process Use Aqua Regia Solvent in Metal Recovery Gold (Au) Waste HP PCB Electronics," *J. Envirotek*, vol. 9, no. 1, pp. 63-68, 2018.
- [8] Y. P. Chandra, "Hydrometallurgical Process External Nickel Use Ore Laterite For Producing MHP," *Research*, 2022.
- [9] D. Permana, R. Kumalasari, W. Wahab, and M. Musnajam, "Leaching Ore Nickel Low Grade Laterite Use Atmospheric Acid Leaching Method in Acidic Media Chloride (HCl)," *Geol. Min. Res.*, vol. 30, no. 2, p. 203, 2020.
- [10] S. S. Shinde *et al.*, "Physical and electrochemical properties of CuO thin films prepared by spray pyrolysis," *Appl. Surf. Sci.*, vol. 257, no. 13, pp. 5868-5872, 2011.
- [11] R. Fauziah, "Solubility CdS and CuS in Gelation Water In Oil System Microemulsion Water, Surfactant SDBS, and Pentanol," *J. Chem.*, vol. 9, no. 2, 2020.
- [12] P. Wu *et al.*, "Synthesis and characterization of CuO nanoparticles by a novel sol-gel method," *Mater. Lett.*, vol. 61, no. 4-5, pp. 1205-1207, 2007.
- [13] J. Wang *et al.*, "Controllable synthesis of CuO nanostructures via a simple precipitation method," *Ceram. Int.*, vol. 39, no. 7, pp. 7825-7831, 2013.
- [14] X. Zhang and G. Wang, "Influence of pH and Temperature on the Morphology of CuO Nanoparticles Prepared by

stages of this study. Their expertise in hydrometallurgical processes and material synthesis has been instrumental in the completion of this manuscript.

AUTHOR CONTRIBUTION

Conceptualization, A.N. and M.K.; methodology, S.J.; software, A.N. and S.J.; validation, M.K. and S.J.; formal analysis, A.N.; investigation, A.N.; resources, A.N.; data curation, M.K. and S.J.; writing—original draft preparation, S.J.; writing—review and editing, A.N. and S.J.; visualization, M.K. All authors have read and agreed to the published version of the manuscript.

- Precipitation," *Cryst. Res. Technol.*, vol. 50, no. 3, pp. 245-252, 2015.
- [15] A. Purwanto *et al.*, "Synthesis of $\text{LiNi}_{0.8}\text{Co}_{0.15}\text{Al}_{0.05}\text{O}_2$ cathode materials by a precipitation method," *J. Alloys Compd.*, vol. 747, pp. 431-438, 2018.
- [16] M. Saravanan, "Effect of processing parameters on the synthesis of CuO nanoparticles," *J. Nanomater.*, vol. 2014, pp. 1-10, 2014.