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Review Article

A Comprehensive Review on Picric Acid: Synthesis, Properties, and Applications

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ABSTRACT

2,4,6-trinitrophenol, the formal name for picric acid, is a highly reactive, multipurpose substance that finds extensive use in a wide range of scientific and industrial fields. Its synthesis, physicochemical characteristics, and various applications are thoroughly examined in this paper. With an emphasis on its functions as a potent explosion, a synthetic colour, and a crucial step in the synthesis of organic compounds, the chemical structure, stability, and reactivity of picric acid are examined. Recent developments have demonstrated its use in bioanalytical methods, electrochemical sensing, and the creation of innovative functional materials, in addition to its conventional uses. Because of its distinct chemical interactions, the substance has been used more and more in analytical chemistry to detect metal ions and biomolecules. Furthermore, interest in its potential in biomedical and pharmaceutical research is growing, especially in the areas of toxicity investigations and medication development. Despite its advantages, picric acid presents serious risks to human health and the environment because of its extreme toxicity, explosiveness, and potential for unintentional detonation if kept incorrectly. In order to reduce risks in industrial and laboratory settings, the evaluation also covers best practices for handling, storing, and disposing of materials. This publication is a useful resource for scholars, chemists, and industrial practitioners dealing with picric acid by combining previous studies and upcoming trends. It seeks to shed light on the benefits and drawbacks of this substance while investigating novel uses that could spur further developments in chemistry, materials science, and pharmaceutical research.

INTRODUCTION

The Greek word picric, which meaning a bitter acid that reflects harshness in taste, is where the phrase came from. Similar to trinitrotoluene, picric acid is a pollutant that is very harmful to human health [afshan saleem *et.al* 2019]. Picric acid is another name for trinitrophenol. Trinitrophenol is widely employed in a variety of industries,

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including polymers, fuel cells, leathers, explosives, medicines, and agriculture. The liver, kidney, eyes, and respiratory system are all seriously endangered by picric acid [Avani Sheth and others, 2010]. In the early 20th century, picric acid was initially employed to measure blood glucose levels. When glucose, sodium carbonate, and picric acid are combined and heated, a red substance is created that can be used to gauge the body's glucose levels. The wet form of picric acid is used to dye skin, which reacts with the skin's protein to turn it dark brown and stays that way for a month [Fabin Magdalena et al., 2023]. The pharmaceutical business uses picric acid widely, as it is supplied as an antiseptic and used to treat burns, herpes, smallpox, and malaria. It is a member of the family of phenols that are extremely acidic. The Greek word picric, which means a bitter acid that reflects harshness in taste, is where the phrase came from. Similar to trinitrotoluene, picric acid is a pollutant that is very harmful to human health [afshan saleem *et.al* 2019]. Picric acid is another name for trinitrophenol. Trinitrophenol is widely employed in a variety of industries, including polymers, fuel cells, leather, explosives, medicines, and agriculture. The liver, kidneys, eyes, and respiratory system are all seriously endangered by picric acid [Avani Sheth and others, 2010]. At the beginning of the twentieth century, picric acid was employed for the first time to measure blood glucose levels. When glucose, sodium carbonate, and picric acid are combined and heated, a red substance is created that can be used to gauge the body's glucose levels. The wet form of picric acid is used to dye skin, which reacts with the skin's protein to turn it dark brown and stays that way for a month [Fabin Magdalena et al., 2023]. Throughout the pharmaceutical sector, picric acid is widely used as an antiseptic to treat burns, smallpox, malaria, and herpes. It is a member of the very acidic phenol family. The Greek word picric, which means a bitter acid that reflects harshness in taste, is where the phrase came from. Like trinitrotoluene, picric acid is widely recognized as a pollutant that poses a serious risk to human health. Trinitrophenol is commonly known as Picric Acid. Trinitrophenol is extensively used in many industries such as fuel cells, leathers, pharmaceuticals, explosive, agriculture and polymer, etc. The liver, kidneys, eyes, and respiratory system are all seriously endangered by picric acid. At the beginning of the twentieth century, picric acid was employed for the first time to measure blood glucose levels. When glucose, sodium carbonate, and picric acid are combined and heated, a red substance is created that can be used to gauge the body's glucose levels. Skin that interacts with the protein in the skin to turn dark brown and stays that way for a month is dyed with picric acid in a moist state. Throughout the pharmaceutical sector, picric acid is widely used as an antiseptic to treat burns, smallpox, malaria, and herpes. It is a member of the very acidic phenol family.[Afshan Saleem et al.2019]. A nitroaromatic molecule with a strongly acidic proton in its hydroxyl group is 2,4,6-trinitrophenol. Especially during World War I, picric acid was a common explosive utilized in the production of explosive charges and weapons. In addition, PA was utilized in chemical labs for the production of fungicides, the dye and pharmaceutical industries, and as one of the elements used to track the automated synthesis of peptides. Because 2,4,6-trinitrotoluene was less responsive to mechanical stimuli and because PA was extremely poisonous, it quickly replaced picric acid in military uses during the interwar years (1919–1939). [Fabin Magdalena et al., 2023]. The fact that phenol and its chemical analogues are inexpensive and valuable raw materials for the synthesis of many products, such as the well-known explosives picric acid, isomeric dinitrophenols, methyl picrate, cresolite, and

styphnic acid, influences the choice of picric acid as the primary working substance. Additionally, we have some expertise synthesizing other alkyl phenols, which could be intriguing substrates for the synthesis of picric acid structural analogues, presumably while retaining their explosive properties. Picric acid's acidic nature causes it to react with the shell's metal shell. This is a significant disadvantage. [Chikhradze, Nikoloz et al., 2021]. Due to a number of variables, including the emergence of new infectious diseases and the rise in multi-drug resistance microbial pathogens, which are especially relevant for Gram-positive bacteria, treating infectious diseases continues to be a significant and difficult problem. Small and among the oldest living things on the planet are bacteria. Bacteria are only visible under a microscope due to their extremely small structure. Bacteria are frequently found in water, the ground, and other living things. [Avani Sheth and others, 2010].

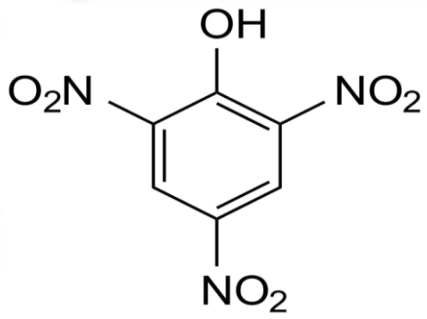


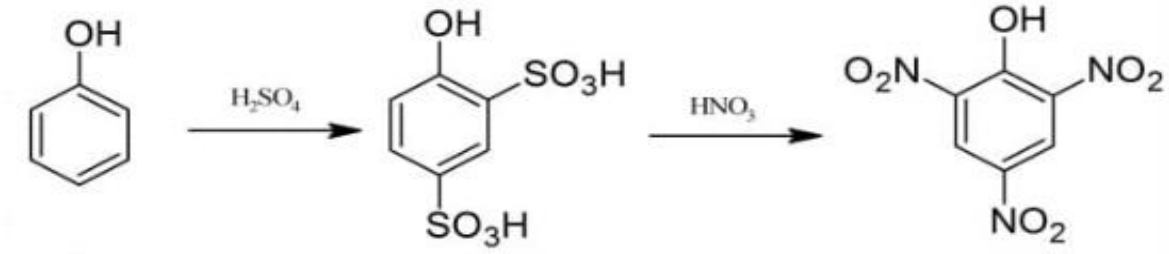
Fig. Structure of picric acid

Chemical name	2,4,6- trinitrophenol
Chemical formula	C6H3N3O7
Molecular mass	229.10 g·mol−1
Appearance	Colorless to yellow solid
Density	1.763 g·cm−3, solid
Melting point	122.5°C (252.5 °F; 395.6 K)
Boiling point	>300°C (572 °F; 573 K) Explodes
Solubility in water	12.7 g·L−1
Vapor pressure	1 mmHg (195°C)
Acidity (pKa)	0.38

[srivastava KK. *Et.al* 2017]

[afshan saleem *et.al* 2019]

Synthesis of picric acid:



Procedure:

1.12.5 grams of phenol and 34.5 milliliters of concentrated sulfuric acid are combined in a porcelain basin, and the combination is heated on a water bath until a limpid phenol-sulfuric acid solution forms. 2.Phenol-sulfuric acid formation typically concludes in 30 to 40 minutes. A 1L flask containing 50 ml of chilled water is filled with a phenol-sulfuric acid solution while being stirred. 3.Water is used to chill the flask. Dropwise additions of 25 ml of concentrated (d=1,4) nitric acid are made while stirring. 4.The reaction mixture turns crimson, the temperature rises, and red vapor emerges—

inhaling is not permitted! Work in the suction cupboard.
5.After setting the flask on the water bath, add the remaining 10 milliliters of nitric acid and heat the mixture for 1.5 to 2 hours.

6.Yellow crystals of picric acid form after cooling. After that, fill the flask with water, stir, filter the crystals, and rinse.
7.50% ethyl alcohol crystallizes to produce 14 g of picric acid at m. p. 1220C. [Chikhradze, Nikoloz et al., 2021].

MECHANISM OF ACTION:

First Contact with the Surface of Bacteria: Picric acid initially comes into touch with the bacterial surface when it is added to bacterial cultures. Passive diffusion over the cell wall is the primary method of this interaction, particularly if the bacterial membrane is susceptible to picric acid.

Arrival to the Bacterial Cell:

Depending on the type of bacteria (e.g., Gram-positive vs. Gram-negative), picric acid can pass through the bacterial cell membrane.
• Gram-negative bacteria may be more difficult for picric acid to penetrate due to their more complicated outer barrier.

Oxidative Stress

Picric acid, like other nitro compounds, might induce oxidative stress within bacterial cells. It can produce reactive oxygen species (ROS) or generate free radicals, which damage cellular components such as lipids, proteins, and nucleic acids, leading to cell dysfunction or death.

Interrupting the Metabolic Processes of Bacteria
Picric acid can interact with biological components once it has entered the bacterial cell. It could impact essential functions like:
• DNA replication: By reacting with the nucleic acids, the trinitrophenol group in picric acid may obstruct the production of bacterial DNA or RNA.

• Proteins: Picric acid can attach to proteins and change their structure or function, which could interfere with vital enzyme functions.
• Electron transport chain: By interacting with enzymes in the electron transport chain, picric acid may also have an impact on the energy production of bacteria by reducing the synthesis of ATP.

Cell Wall Integrity Disruption
Picric acid may cause direct or indirect harm to the bacterial cell wall. The bacterial cell's structural integrity would be weakened by the breakdown of the cell wall, especially in Gram-negative bacteria, leaving it more vulnerable to lysis or osmotic stress.

Bacterial Death or Inhibition

These consequences can cause bacterial cells to rupture their cell membranes, lose intracellular material, or become unable to perform vital life functions, which can ultimately result in bacterial death or growth suppression.

APPLICATION:

Because of its high nitrogen content and susceptibility to heat and impact, picric acid has been employed as an explosive for a long time. During World Wars I and II, it was employed in the manufacture of mines, grenades, and explosive shells. Trinitrophenol or explosive picric acid are common names for the explosive version of picric acid.
Picrate salts: Picric acid reacts with metals to generate picrate salts, which are frequently more stable and have the potential to be explosive substances. For instance, artillery shells employed lead picrate as a detonator. Picric acid is still utilized in some applications where great

sensitivity and explosive strength are required, although its employment as a principal military explosive has decreased due to its sensitivity.

Gravimetric Analysis: Metal ions, including alkaline earth metals (such as calcium, magnesium, and barium), are detected and quantified in labs using picric acid. The concentration of these metals can be ascertained by weighing the insoluble picrate salts that are produced when picric acid reacts with them. **Reagent in Organic Synthesis**: In organic chemistry, it is also employed as a reagent for the detection of bases and other chemicals, particularly in colorimetry, where a detectable color shift can be produced by its interaction with specific molecules.

Analytical Chemistry Titration: Picric acid can be used in titration procedures, especially in basic and acidic reactions. **Antiseptic**: In the past, picric acid was used to treat burns and as an antiseptic. Because picric acid has antibacterial qualities, it was employed in a solution known as Burnet's Solution in the early 20th century to treat burn injuries. However, because of its toxicity and the advancement of more potent medicines, this use has been mainly phased out.

Drug Delivery Research: The potential of picric acid in drug delivery systems and its interactions with biological components have been the subject of current studies. According to certain research, its compounds may find use in medical imaging and cancer treatment.

Historical Use in Dyeing: Especially in the late 19th and early 20th centuries, picric acid was employed as a yellow dye in the textile industry. When the chemical reacts with fibers, it can produce yellow-colored salts, which have been used to color textiles. Synthetic Dyes: Synthetic dyes for leather, wool, and other textiles have also been made using picric acid as a component. However, because of its risky nature and the availability of safer substitutes, its use in this sector has decreased.

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CONCLUSION:

Picric acid (2,4,6-trinitrophenol) stands as a historically significant and chemically potent compound with a wide array of applications across multiple domains. Derived from the Greek word pikros, meaning “bitter,” this highly nitrated phenol possesses both beneficial chemical reactivity and notable toxicity. Initially recognized for its role in explosives and early glucose testing methodologies, picric acid has evolved into a compound of multidisciplinary relevance. The review of its applications reveals that pic[ric acid has been extensively employed in the manufacture of munitions due to its explosive power, particularly in the form of picrate salts. In analytical and organic chemistry, it serves as a valuable reagent in colorimetric analysis, gravimetric determination of metal ions, and titration processes. Historically used as an antiseptic and dye, its role in the pharmaceutical and textile industries is now limited due to safety concerns. Nonetheless, ongoing research continues to explore its utility in modern scientific areas such as drug delivery and cancer therapeutics. Despite its hazardous nature, picric acid remains a compound of scientific interest due

to its structural versatility and reactive potential. This review emphasizes the need for continued research into safer derivatives and advanced applications while also recognizing the historical and ongoing importance of picric acid in chemistry, medicine, and industry.

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