Tungsten Acid Encyclopedia

中钨智造科技有限公司

CTIA GROUP LTD

CTIA GROUP LTD

Global Leader in Intelligent Manufacturing for Tungsten, Molybdenum, and Rare Earth Industries

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INTRODUCTION TO CTIA GROUP

CTIA GROUP LTD， a wholly-owned subsidiary with independent legal personality established by CHINATUNGSTEN ONLINE , is dedicated to promoting the intelligent, integrated, and flexible design and manufacturing of tungsten and molybdenum materials in the Industrial Internet era. CHINATUNGSTEN ONLINE, founded in 1997 with www.chinatungsten.com as its starting point—China's first top-tier tungsten products website—is the country's pioneering e-commerce company focusing on the tungsten, molybdenum, and rare earth industries. Leveraging nearly three decades of deep experience in the tungsten and molybdenum fields, CTIA GROUP inherits its parent company's exceptional design and manufacturing capabilities, superior services, and global business reputation, becoming a comprehensive application solution provider in the fields of tungsten chemicals, tungsten metals, cemented carbides, high-density alloys, molybdenum, and molybdenum alloys.

Over the past 30 years, CHINATUNGSTEN ONLINE has established more than 200 multilingual tungsten and molybdenum professional websites covering more than 20 languages, with over one million pages of news, prices, and market analysis related to tungsten, molybdenum, and rare earths. Since 2013, its WeChat official account "CHINATUNGSTEN ONLINE" has published over 40,000 pieces of information, serving nearly 100,000 followers and providing free information daily to hundreds of thousands of industry professionals worldwide. With cumulative visits to its website cluster and official account reaching billions of times, it has become a recognized global and authoritative information hub for the tungsten, molybdenum, and rare earth industries, providing 24/7 multilingual news, product performance, market prices, and market trend services.

Building on the technology and experience of CHINATUNGSTEN ONLINE, CTIA GROUP focuses on meeting the personalized needs of customers. Utilizing AI technology, it collaboratively designs and produces tungsten and molybdenum products with specific chemical compositions and physical properties (such as particle size, density, hardness, strength, dimensions, and tolerances) with customers. It offers full-process integrated services ranging from mold opening, trial production, to finishing, packaging, and logistics. Over the past 30 years, CHINATUNGSTEN ONLINE has provided R&D, design, and production services for over 500,000 types of tungsten and molybdenum products to more than 130,000 customers worldwide, laying the foundation for customized, flexible, and intelligent manufacturing. Relying on this foundation, CTIA GROUP further deepens the intelligent manufacturing and integrated innovation of tungsten and molybdenum materials in the Industrial Internet era.

Dr. Hanns and his team at CTIA GROUP, based on their more than 30 years of industry experience, have also written and publicly released knowledge, technology, tungsten price and market trend analysis related to tungsten, molybdenum, and rare earths, freely sharing it with the tungsten industry. Dr. Han, with over 30 years of experience since the 1990s in the e-commerce and international trade of tungsten and molybdenum products, as well as the design and manufacturing of cemented carbides and high-density alloys, is a renowned expert in tungsten and molybdenum products both domestically and internationally. Adhering to the principle of providing professional and high-quality information to the industry, CTIA GROUP's team continuously writes technical research papers, articles, and industry reports based on production practice and market customer needs, winning widespread praise in the industry. These achievements provide solid support for CTIA GROUP's technological innovation, product promotion, and industry exchanges, propelling it to become a leader in global tungsten and molybdenum product manufacturing and information services.

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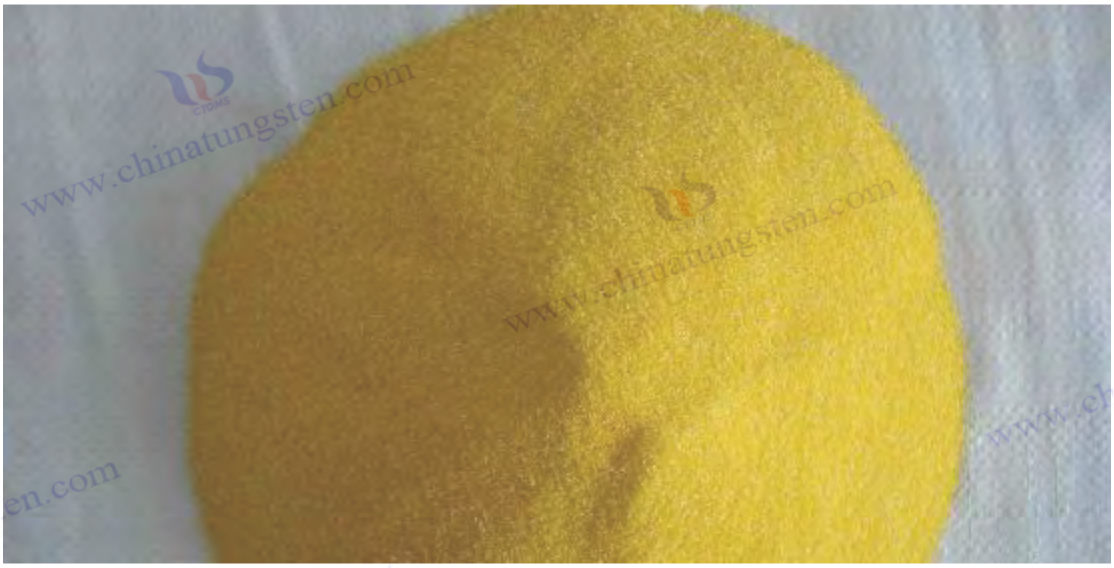

Preface

Writing background and significance

Tungstic acid (chemical formula H_2WO_4) is one of the most basic and structurally diverse inorganic acids in the tungsten chemical system. Since it was first separated in the 19th century, it has gradually evolved into a core intermediate in modern tungsten material science, inorganic synthetic chemistry and functional material technology. It is not only an important precursor for a variety of tungsten compounds (such as tungstates, metatungstates, tungstates and tungsten oxides), but also a class of functional materials with potential application value.

In key strategic areas such as energy transformation, new material development, and green chemistry, tungstic acid and its derivatives have shown broad application prospects. For example, in emerging applications such as photocatalytic degradation, water treatment, supercapacitors, and electrochromic devices, tungstic acid has attracted much attention due to its excellent redox ability, multi-level crystal structure, and ion migration characteristics. In addition, tungstic acid also has an irreplaceable position in traditional industries such as inorganic salt preparation, tungsten metal extraction, high-temperature ceramic synthesis, and chemical analysis reagents.

With the continuous advancement of the global "localization of high-performance metal materials", "green metallurgy" and "new energy driven material transformation", tungstic acid, as a key node connecting tungsten resources and high-end functional materials, its comprehensive performance, preparation technology, application path, environmental impact and market potential urgently need to be systematically sorted out and deeply studied.

In this context, the compilation of the "Encyclopedia of Tungsten Acid" is not only intended to summarize the current research results and industrial practices in the field of tungsten acid at home and abroad, but also to provide scientific research institutions, engineering and technical personnel, high-end user companies and policy decision-making departments with an authoritative, systematic and operational knowledge framework and technical basis.

The strategic value of tungstic acid

The importance of tungstic acid can be understood from the following four dimensions:

1. **Strategic resource bridge role**
   Tungstic acid is the transition form between APT (ammonium paratungstate) to tungsten metal and tungsten oxide, and occupies a key position in the tungsten industry chain.
2. **Material R&D Platform Characteristics**
   Tungsten acid has material engineering capabilities such as regulating crystal form, doping metal ions, and constructing porous structures. It is an important platform molecule for the preparation of nano- tungsten materials, multi-acid coordination structures, and composite catalytic materials.
3. **Green manufacturing and functional applications are compatible with**
   its water solubility and controllable precipitation, making it suitable for wet green preparation routes and meeting the requirements of energy conservation and emission reduction. At the same time, tungstic acid and its salts have multifunctional conductivity, photocatalysis, thermal stability and other properties, and have both scientific research and application value.
4. **The basic unit for building international discourse power.**
   At present , the export control of tungsten resources is gradually strengthened. Tungsten acid and its extended products have become an important export form of China's strategic metal resources "going out". The relevant standardization and industrialization level directly affect China's discourse power in the international supply chain of high-end materials.

How this book is structured

This book starts from the basics and gradually goes deeper, adopting an approach that emphasizes both theory and practice, and combines industry with the forefront. It is divided into twelve chapters and four appendices:

- **Chapters 1-2** : Overview of the basic concepts, development history and physical and chemical properties of tungstic acid, providing theoretical support for subsequent chapters;
- **Chapters 3-4** : Detailed description of various mainstream preparation methods and characterization techniques, including China Tungsten Intelligence 's proprietary process references;
- **Chapters 5-6** : Introducing common tungstic acid derivatives and their application in inorganic industry;
- **Chapters 7 to 9** : Focus on the latest developments in tungstic acid in the fields of energy materials, analytical chemistry, functional coatings and biological applications;
- **Chapter 10** : Focus on the safety, storage and transportation specifications and environmental management of tungstic acid throughout its life cycle;

- **Chapters 11-12** : Provides a panoramic analysis of the industry chain, market, policies and development trends, which is conducive to investment judgment and strategic research;
- **Appendix** : Provides a glossary, standard comparison, literature index and CTIA GROUP Technology Service Information to enhance readers' reference and application efficiency.

This book covers the full dimensions of basic theory, engineering technology, standards and specifications, market trends and green manufacturing. It can be used as a database for scientific researchers, an operating manual for engineers, a teaching aid for university teachers and students, and a decision-making reference for the government and industry.

Target audience and usage

This book is suitable for the following groups:

- **Researchers and material engineers** : systematically understand the physical and chemical properties and experimental paths of tungstic acid to help scientific research design and material optimization;
- **Powder processing and metallurgy practitioners** : obtain practical experience in preparation and application to support the stable production of high-quality tungstic acid powder;
- **Environmental and safety managers** : Understand the environmental behavior, safe transportation and storage specifications of tungsten acid to ensure clean production and compliance with regulations ;
- **College teachers and graduate students** : used as teaching reference, graduation thesis writing, and basic literature for project application;
- **Industry analysts and relevant government departments** : understand the trends of the tungstic acid industry chain, policy trends and technical barriers, and assist in formulating development plans.

Readers are advised to select chapters to consult according to their own needs; this book provides cross-indexing and appendix navigation to help technicians quickly locate key content in actual projects.

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Chapter 1 Basic Concepts and Historical Development of Tungstic Acid

Tungstic acid (chemical formula H_2WO_4) is an oxygen-containing acid composed of tungsten in the +6 valence state with oxygen and hydrogen . It is one of the most important intermediates in tungsten-based chemistry . It is not only widely used in tungsten smelting and tungsten salt preparation processes, but also exhibits unique physical and chemical properties and application value in many cutting-edge fields such as functional materials, biocatalysis, and photoelectric conversion.

1.1 Definition and classification of tungstic acid

Basic Definition

Tungstic acid usually refers to a yellow amorphous or crystalline solid precipitated by the reaction of tungstates (such as sodium tungstate, ammonium tungstate) with strong acids under neutral or weakly acidic conditions. The most common form of its chemical formula is $H_2WO_4 \cdot xH_2O$ (i.e. hydrated tungstic acid) . Its actual composition is closely related to the reaction conditions, so it presents a certain structural diversity.

Classification

According to its structure, hydration state, reactivity and preparation conditions, tungstic acid can be divided into the following categories:

Classification basis	type	feature
Hydration level	Anhydrous tungstic acid (H_2WO_4) Hydrated tungstic acid ($H_2WO_4 \cdot xH_2O$)	Anhydrous bodies are rare, and hydrated tungstic acid is the main form of tungstic acid in industry.
Structural form	Amorphous tungstic acid Crystalline tungstic acid	The crystalline state is orthorhombic or monoclinic, and the amorphous state is a colloidal precipitate.
Synthesis method	Wet Chemical Tungstic Acid	The former is used to prepare metatungstate, and

	Pyrolysis Tungstic Acid	the latter is used as a raw material for tungsten metal.
Derivative Capabilities	Monomeric Tungstic Acid Polymeric Tungstic Acid	Can polymerize to form complex structures such as metatungstate and polytungstate

Tungstic acid is usually bright yellow or yellow-green powder, soluble in hydrofluoric acid, ammonia or alkali solution, insoluble in cold water and alcohol, and has weak acidity and high thermal stability.

1.2 The discovery and naming evolution of tungstic acid

The tungsten element was first discovered by Swedish chemist Carl Wilhelm Scheele in 1781. The original ore (wolfsone) was treated with hydrochloric acid to obtain a yellow precipitate, known as "tungstate precipitate", which was the prototype of early tungstic acid. In 1783, the Spanish brothers Juan and Fausto Elhuyar further reduced the yellow substance with carbon and produced metallic tungsten for the first time.

In the early 19th century, tungstic acid gradually became an important representative in the study of metal oxidation states and acid-base reactions in European laboratories. With the development of inorganic chemistry, tungstic acid was systematically classified into the hexavalent metal oxoacid system and gradually formed a relatively standard naming system with molybdic acid, niobic acid, etc.

The term "tungstic acid" began to be concretized and subdivided into a variety of species with clear structures, including monotungstic acid, metatungstic acid (such as $H_2W_{12}O_{40}$) , heteropolytungstic acid , etc.

In China, the systematic study of tungstic acid began in the 1950s, especially in areas with concentrated tungsten mineral resources such as Jiangxi, Hunan and Henan. The research on its wet preparation process and crystallization control has promoted the development of tungsten salt chemistry in China.

1.3 The status of tungstic acid in inorganic chemical system

Tungstic acid is one of the most important compounds of tungsten in its high oxidation state . Its acidity, coordination and derivatization properties lay the foundation for its wide application in inorganic chemistry.

The functional status is as follows:

- **Coordination center :** W^{6+} in tungstate can form stable multi-nuclear complexes with ligands such as O, N, and S, and is an important center for the synthesis of multi-metal complexes;

- **Building unit** : Tungstic acid is often used as the basic skeleton of polyanion frameworks (such as Keggin structure) to construct isopoly acids and polytungsten oxides ;
- **Acid-base reaction template** : Because it has different forms at different pH values, it is an important model for studying reactions such as acidolysis-precipitation-complexation-recombination;
- **Fundamentals of crystal engineering** : It can form a variety of crystal morphologies at different temperatures and solution concentrations, and is a typical object of crystal control and inorganic nanomaterial research.

Tungstic acid is also a comparative material for studying other transition metal acids (such as chromic acid and molybdic acid) and is often used as a structural control carrier for electronic, photon and magnetic properties.

1.4 The main history and technical milestones of tungstic acid research

In the past two centuries, the research on tungstic acid has gone through three stages: from "empirical extraction" to "structural analysis" and then to "functional application":

stage	time	Features
Start-up	Late 18th century–mid 19th century	Extraction and precipitation of tungstate in the laboratory, lack of structural knowledge
Analysis Phase	First half of the 20th century	Begins using X-ray diffraction, infrared spectroscopy and other methods to confirm structure
Function expansion stage	1970s to present	Focus on catalysis, optoelectronics, energy storage and composite functional materials

Representative technological breakthroughs:

- **1955 : Crystalline H_2WO_4** was synthesized for the first time under hydrothermal synthesis conditions , and a standard physical property curve was established;
- **1983 : The** Keggin structure of polytungstate was established, opening a new era of research on polyoxometalates;
- **2005** : A breakthrough was made in the preparation technology of nano-tungstic acid, which promoted its application in photocatalysis and supercapacitors;
- **In the past decade** : CTIA GROUP and other domestic companies have developed high-purity ultrafine tungstic acid industrial-grade products, realizing the transformation of product applications from raw material level to functional level .

Summary

This chapter reviews the chemical definition, development history, academic status and research evolution path of tungstic acid, providing a clear historical background and chemical framework for its preparation, characterization, derivative construction and application path in subsequent chapters. Tungstic acid is not only a basic inorganic species, but also the core node connecting resources, theories and functional applications in the tungsten material science system.

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Chapter 2 Physical and Chemical Properties of Tungstic Acid

Tungstic acid (H_2WO_4) is a typical hexavalent tungsten compound. Its physical appearance, crystal structure, chemical reaction characteristics and multi -physical field performance determine its applicable boundaries in the chemical industry, materials science and application technology. This chapter will systematically analyze the intrinsic properties of tungstic acid from molecular structure to functional properties, laying the foundation for its subsequent process preparation, derivatization and functional application.

2.1 Molecular structure and crystal structure analysis

Molecular composition

The chemical formula of tungstic acid is usually H_2WO_4 , but it often exists in a hydrated form in water, such as $H_2WO_4 \cdot xH_2O$ (x is usually 1-2). The tungsten atom is in a +6 oxidation state, and the surrounding coordination forms an [WO_6] octahedral unit, forming the inorganic acid molecular structure .

Crystal structure

Tungstic acid can show different crystal forms, and its structure is greatly affected by the synthesis conditions. Common crystal types are as follows:

- **Monoclinic** : The most common crystalline form, the unit cell contains chains of [WO_6] octahedrons connected by oxygen bridges to form a two-dimensional structure;
- **Orthorhombic system** : common in rapid precipitation or low temperature crystallization conditions;
- **Triclinic or amorphous** : formed in disordered precipitation or rapidly cooling systems, often appearing as a colloidal or loose powder.

Crystal analysis methods usually use:

- X-ray powder diffraction (XRD): used to determine the crystal form and lattice constant;

- Scanning electron microscope (SEM): observe the surface morphology and crystal aggregation state;
- Electron backscatter diffraction (EBSD): study the arrangement and preferred orientation of grains in micro areas.

2.2 Thermal stability and decomposition behavior

As a high-valent metal oxide acid, tungstic acid exhibits excellent thermal stability. In air or inert atmosphere, its thermal decomposition behavior is as follows:

- **<100°C** : Loss of physically adsorbed water;
- **100–300°C** : Hydrated tungstic acid gradually loses water and turns into anhydrous H_2WO_4 or $WO_3 \cdot xH_2O$;
- **300–450°C** : Crystal water begins to be removed, the structure shrinks, and WO_3 is formed ;
- **＞600°C** : Stably converted into yellow tungsten trioxide (WO_3), which is the precursor for most downstream applications.

Commonly used thermal analysis techniques:

- Thermogravimetric analysis (TGA): monitors mass changes;
- Differential Scanning Calorimetry (DSC): Determine phase change point and endothermic and exothermic behavior;
- Combination of FTIR and Raman: Determine the transformation process of hydroxyl and W–O bond .

Conclusion: Tungstic acid can exist stably at room temperature and has a clear thermal decomposition path. It is a high-quality precursor suitable for preparing functional oxides after heat treatment.

2.3 Acidity, alkalinity and solubility characteristics

Acidity and alkalinity

- Tungstic acid is weakly acidic in water and has a low degree of ionization;
- tungstate ions (WO_4^{2-} , $W_{12}O_{42}^{10-}$, etc.) in the presence of strong base ;
- It precipitates as colloidal tungstate at pH < 1 and exists as polymerized tungstate in the pH range of 2-6.

Its acid-base behavior shows an amphoteric trend, and the differences in behavior at different pH values are as follows:

pH range	Existence	Chemical behavior
＜1	Colloid precipitation	Co-precipitation with metal ions
2–6	Metatungstate	Polymer formation
>8	WO_4^{2-} ions	Soluble in alkali

Tungstic acid is often used to adjust the form of tungsten in solution and is representative in polyacid synthesis and acid-base buffer systems.

Solubility

- **Insoluble in cold water and ethanol** , slightly soluble in hot water;
- **Soluble in alkaline solution** : such as ammonia water, NaOH, etc., to generate stable tungstate;
- **Dissolved in hydrofluoric acid (HF)** : forms volatile tungsten-fluorine complex ;
- It is a poorly soluble yellow precipitate in acidic solution.

Its solubility characteristics have important guiding significance for hydrometallurgy , regeneration and recovery, and preparation of precursor solutions.

2.4 Optical, electrical and magnetic properties

Tungstic acid exhibits several important optoelectronic functional properties under specific structures and particle sizes, which are the theoretical basis for its application in the fields of photocatalysis, electrochromism, sensors and optoelectronic materials.

Optical performance

- Tungstic acid is yellow due to W^{6+} → Charge transfer of O^{2-} ;
- The optical band gap is generally 2.6–2.8 eV, which is a wide band gap semiconductor;
- Nano-tungstic acid or doped tungstic acid has adjustable band gap, which is suitable for visible light absorption catalysis;
- Under ultraviolet light, it can participate in electron transitions and generate free electron-hole pairs.

Electrical properties

- The bulk tungstic acid is an insulator, but after being doped (such as Cu, Ag) or forming a non-stoichiometric structure, it can have a certain conductivity;
- Porous tungstate films show electrochromic phenomena and are suitable for smart windows and displays.

Magnetic properties

- Pure tungstic acid is not magnetic;
- After being doped with transition metal elements (such as Fe and Co), it can exhibit weak magnetic response and is suitable for magnetically responsive nanocarriers.

2.5 Study on isomers and polymorphs of tungstic acid

Tungstic acid can form a variety of structural isomers and polymers under different conditions. These forms differ significantly in physical stability, catalytic activity, and adsorption properties.

Common heterogeneous types

- **Monomer H_2WO_4** : simple structure and high activity;
- **Poly$H_6W_{12}O_{40}$:** Keggin **- type polyanion** , used in catalysis **;**
- **Heteropoly acid tungstates** : such as phosphotungstic acid, silicotungstic acid, etc., have selective oxidation ability.

Polymorphic behavior

- Polymorphs can be formed at different temperatures, such as α-H_2WO_4 and β-H_2WO_4 ;

- Changes in hydration state affect crystal spacing and thermal decomposition temperature;
- lamellar and other structures can be induced in hydrothermal and heterogeneous systems .

Crystal form regulation is one of the core technologies for the functional development of tungstic acid, which has a significant impact on its subsequent catalytic activity, interfacial reactivity and film-forming properties.

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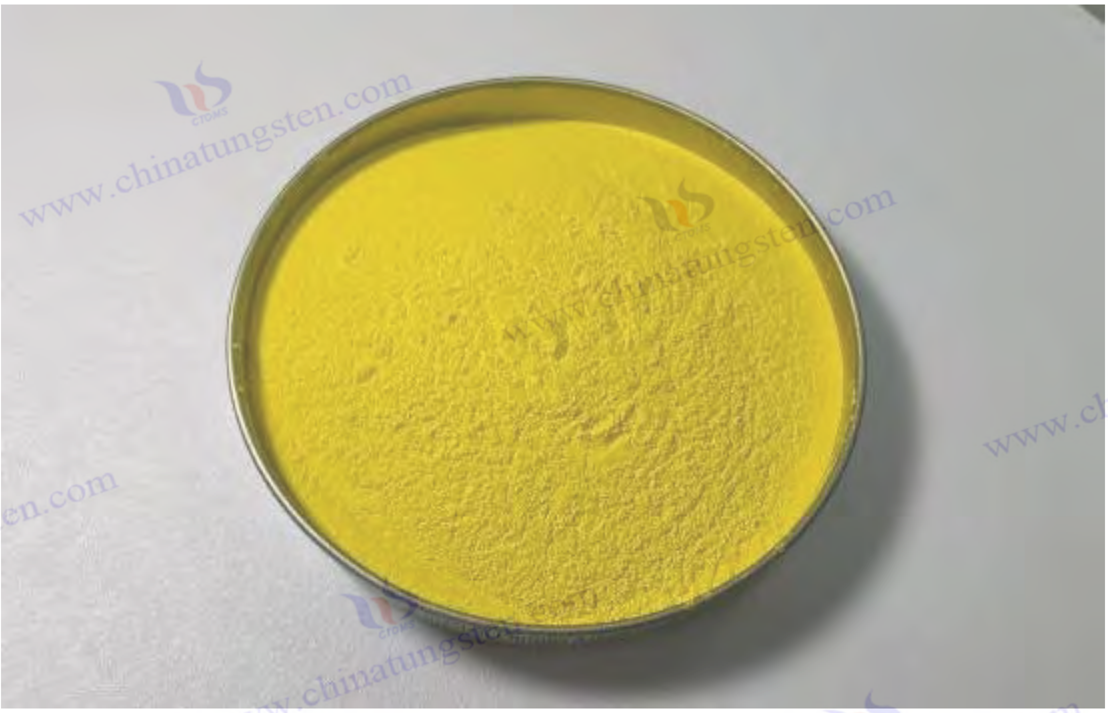

Chapter 3 Preparation of Tungstic Acid

3.1 Preparation of tungstic acid from APT

APT (Ammonium Paratungstate) is one of the most important intermediates in the tungsten industry chain and the most commonly used raw material for the industrial-scale preparation of tungstic acid. The metatungstate ions contained in APT can be completely converted into tungstic acid precipitation under appropriate acidic conditions. Therefore, this route is widely used in laboratories, industries, and the preparation of precursors for high-purity tungsten products.

1. Process principle

The chemical formula of APT is usually $(NH_4)_{10}[H_2W_{12}O_{42}] \cdot 4H_2O$, which is a highly polymerized ammonium tungstate salt. Under the action of dilute acid (such as nitric acid and hydrochloric acid), APT gradually releases NH_4^+ ions and undergoes polymer dissociation to generate tungstate precipitate. The basic reaction is as follows:

(NH4) 10 [H2 W12 O42] + 10H+→12H2 WO4 ↓ +10NH4 +

- This reaction belongs to ion exchange precipitation reaction;
- The process is accompanied by the formation of tungstate precipitation, the construction of hydration structure and crystal growth.

2. Main raw materials and equipment requirements

Raw material requirements:

- **APT powder** , purity ≥99.95%, used after drying;
- **Acid solution** , usually dilute nitric acid or dilute hydrochloric acid (concentration 1–3

mol/L);

- **Deionized water** , control the metal ion impurity content below 0.5 ppm.

Core equipment configuration:

Device Name	effect
Stainless steel stirred reactor (acid resistant lining)	Achieve uniform mixing and reaction between APT and acid
Constant temperature water bath or jacket control system	Controlling reaction temperature
Vacuum filter or filtration equipment	Separation of precipitated tungstic acid and mother liquor
Drying oven (air blower/vacuum)	Dry finished tungstate powder

If high-purity tungstic acid is to be prepared, an air purification system, an argon protection system and a neutral cleaning unit are also required.

3. Process Overview

The typical APT to tungstate process is as follows:

1. **Acid preparation : dilute**
   HNO_3 or HCl to the required concentration and pre-cool or heat to the set temperature (usually 25–50°C).
2. **APT addition and stirring reaction**
   Slowly add APT to the acid solution, control the stirring rate (300-500 rpm), and the reaction lasts for 30-90 minutes. During this period, maintain a constant temperature and prevent agglomeration.
3. **Precipitation formation and aging**
   After the initial tungstic acid precipitate is formed, continue to stir and let stand for 1-3 hours to promote crystal maturation and deamination reaction.
4. **Solid-liquid separation**
   uses vacuum filtration or pressure filtration to separate tungstic acid precipitate and mother liquor, and the residual liquid can be recycled for acid preparation.
5. **Washing and Drying**
   Wash the precipitate 3–5 times with deionized water (to prevent residual impurities), and then dry it at 80–100°C with air blowing or in a vacuum.
6. **Finished Product Packaging and Analysis**
   Tungstic acid powder is sealed and stored, and quality tests such as moisture content, purity, particle size distribution, and XRD are carried out.

4. Key process parameter control

parameter	Recommended value	Control Purpose
pH endpoint	1.5–2.0	Ensures complete precipitation of tungstic acid without forming heteropolyacids
temperature	30–50°C	Balancing dissolution rate and crystal quality
Reaction time	≥ 60 minutes	Ensure that APT is completely decomposed and fully reacted
Filtration rate	＜5 minutes/100mL	Prevent tungstate sol from blocking the filter and improve operating efficiency
Conductivity of	＜20 μS /cm	Control the residual impurity ions (Cl^- , NO_3^- , NH_4^+)

washing liquid		

Note: If you need to prepare micron-sized spherical tungstate powder, you can add surfactants (such as PEG-400) during the crystallization stage to assist in regulating the particle morphology.

5. Typical product properties

The obtained tungstic acid products generally have the following physical and chemical indicators:

nature	Parameter range
Appearance	Yellow or light yellow powder
Tungsten content (measured in WO_3)	≥90%
Oxygen content	≥15.5% (theoretical value)
Particle size D50	2–10 µm
Crystal form	Monoclinic or orthorhombic H_2WO_4
Total impurities	≤300 ppm (industrial grade) ≤100 ppm (electronic grade)

6. Advantages and Disadvantages Analysis

project	advantage	insufficient
Process stability	The route is mature and repeatable	Slow reaction kinetics
Source of raw materials	APT is generally available	Affected by the price of tungsten raw materials
Product Control	Easy to obtain high purity H_2WO_4	Crystal form and particle size control need to be optimized
Environmental protection	Mild reaction conditions, no heavy metal pollution	Mother liquor nitrogen-containing wastewater needs to be treated

VII. Application Cases and Industrial Practice (CTIA GROUP)

CTIA GROUP has accumulated a lot of industrial practice experience in the APT to tungstic acid route, and has built three types of tungstic acid production process platforms: batch level , test level, and high-purity level:

- **Industrial batch tungstic acid production line** : annual production capacity ≥ 200 tons, using continuous reaction + automatic filtration + online detection system;
- **Electronic grade tungstic acid preparation laboratory** : equipped with an ammonia-free system, product impurities are controlled to below 50 ppm;
- **Customized system** : Directed control of particle size (D50=1–5 µm), specific surface area, dispersion performance, etc. according to downstream needs.

At the same time, the company provides REACH-compliant tungstic acid MSDS and origin certification for the export market to meet international market access requirements.

The APT route is one of the most reliable and standardized process routes for preparing tungstic acid. It has the advantages of simple operation, mild reaction and stable product. It is suitable for scientific research experiments, high-purity tungsten salt production and bulk industrial use. By optimizing and controlling key parameters such as acid concentration, temperature, reaction time, and washing efficiency, high-purity tungstic acid products with controllable particle size can be stably obtained, providing a solid foundation for subsequent derivatization.

3.2 Wet extraction of tungstic acid from WO_3

In addition to the APT route, tungsten trioxide (WO_3), as another stable and readily available intermediate, can also be converted into tungstic acid by wet acid hydrolysis. This method is particularly suitable for waste recycling in tungsten metallurgical processes, closed-loop manufacturing of recycled tungsten powder systems, and customized tungstic acid preparation for non-APT systems. It is one of the flexible process routes commonly used in laboratories and small batch production.

1. Process principle

Tungsten trioxide (WO_3) is difficult to dissolve directly in acidic media, but under certain conditions (heating + complexation), it can react with strong acid or complexing agent to generate metatungstate ions, and reprecipitate into tungstic acid during neutralization or cooling.
The basic reaction pathway is as follows:
$WO3\ (s)+2H^{+}+xH2\ O \rightarrow H2\ WO4 \cdot xH2\ O \downarrow$
In addition, in special media containing HF, NH_4^+ , citric acid, etc., a variety of tungstate complex ions can be generated, which are released into precipitated tungstate after the reaction system is adjusted.

2. Raw material requirements and applicable conditions

raw material	Require
Tungsten trioxide (WO_3)	Powder, purity ≥99.9%, particle size <50 µm
acid solution	HNO_3 , HCl or H_2SO_4 (concentration 1–2 mol/L)
Complexing auxiliary agent (optional)	NH_4Cl , citric acid, acetic acid, etc., used to adjust the reaction kinetics
Other additives	Surfactants or dispersants (such as Tween-20, PEG)

3. Process

1. **WO_3 pretreatment: Dry**
   the WO_3 powder at 80°C for 2 hours to remove physically adsorbed water; if it is recycled material, it needs to be acid washed to remove impurities.
2. **Acid dissolution treatment:**
   Add acid solution preheated to 60–90°C into the reactor, slowly add WO_3 and stir to react for 30–60 minutes to form a stable yellow dispersion or tungstate colloid.
3. **Adjust pH to induce precipitation**
   Slowly add ammonia or alkali solution (such as NaOH) to the system to a pH of about 2-3 to promote polymerization and precipitate tungstic acid.

4. **Maturation and crystallization**
   : Let the mixture stand for 1-2 hours or stir at a low speed to enhance crystal growth and migration of impurities to the mother liquor.
5. **Filtration and washing: The precipitate was collected**
   using a microporous filtration device and washed repeatedly with warm water 3–4 times until the conductivity was <20 μS /cm.
6. **Drying and crushing**
   After drying at 80-100°C for 12 hours, lightly crush it to obtain the yellow tungstic acid product.

4. Key process control parameters

parameter	Control scope	illustrate
Acid concentration	1–2 mol/L (HNO_3 / HCl)	Prevent WO_3 colloid from re-dissolving
temperature	60–90°C	Improve reaction rate and conversion efficiency
pH Adjustment Rate	≤0.5/min	Avoid too fast alkalization to cause agglomeration and precipitation
Reaction time	30–60 minutes (+ aging 1–2h)	Ensure complete reaction and stable crystal structure
Stirring speed	200–400 rpm	Powder suspension is sufficient but vortex is avoided

V. Product performance and applicability

This process can produce tungstic acid with the following characteristics:

project	Performance Indicators
Appearance	Light yellow-yellow microcrystalline powder
Crystal form	Mostly monoclinic/orthorhombic hydrated tungstate
Impurities (Fe, Si, Al)	≤200 ppm (can be controlled by pickling)
Particle size	D50 ≈ 1–5 μm
Specific surface area	8–15 m^2/g (BET)

6. Comparison of process advantages and disadvantages

project	Advantages	insufficient
Availability of raw materials	WO_3 is commonly found in metallurgical by-products	Recycled materials need to be pre-treated to remove impurities
Process Equipment	No special equipment required, suitable for small batch production	Difficult to control continuously
Product Control	The particle size and crystal form can be adjusted by controlling the precipitation process	Impurity control is slightly more difficult than APT method
Economical	Suitable for low-cost tungsten powder conversion	Acid consumption and wastewater treatment burden are high

The wet process for preparing tungstic acid from tungsten trioxide has become an important supplement to the APT process due to its flexibility, resource adaptability and experimental friendliness. This process is particularly suitable for the utilization of recycled materials, non-APT raw material routes and low-cost preparation of precursors for the synthesis of functional materials, providing a reliable solution for green manufacturing and refined control.

3.3 Preparation technology of nano-tungstic acid (sol-gel, hydrothermal, microemulsion, etc.)

With the rapid development of nanomaterials science, traditional micron-sized tungstic acid can no longer meet the requirements of functional applications for particle size control, specific surface area, morphology regulation and interfacial activity. Nano tungstic acid has become a research focus in cutting-edge technologies such as new energy, electronics, photocatalysis and biomaterials due to its extremely small particle size, high dispersibility and excellent photoelectrocatalytic performance.

In order to prepare high-performance nano-tungstic acid, researchers and the industry have developed a variety of wet chemical routes, including sol-gel method, hydrothermal method, microemulsion method, template method, ion exchange method, etc. This section will focus on three representative processes and explore their applicability and scale-up potential.

1. Sol-Gel Method

Process principle

The sol-gel method is a method of forming a stable colloidal sol by forming a tungstate precursor in a solution, and then forming nanoparticles through aging, drying, and heat treatment. Tungstic acid is often used as a precursor to form a three-dimensional network structure.

The typical reaction pathway is:

$Na_2WO_4 + HCl \rightarrow H_2WO_4 \cdot xH_2O \rightarrow [WO_6]_n - Sol \rightarrow Gel \rightarrow Nanoparticles$

Process steps

1. **Precursor preparation** : Dissolve sodium tungstate or ammonium tungstate in deionized water and adjust the pH to 1–2;
2. **Sol generation** : Induce the formation of tungstate colloid by slowly adding dilute acid (such as HCl);
3. **Aging and gel transformation** : Stable gel is formed by leaving it at room temperature for several hours to several days;
4. **Drying** : Low-temperature drying (40–80°C) to remove free water;
5. **Heat treatment and crystallization** : A mild heat treatment at 200–400°C is performed to obtain crystalline or quasi-crystalline nano-tungstic acid.

Features and Applications

Features	describe
Particle size control	10–100 nm tunable

Specific surface area	Up to 60–120 m²/g
Defect Control	Suitable for oxygen vacancy regulation and enhanced photocatalytic performance
limit	The drying process is prone to shrinkage and particle agglomeration needs to be optimized
Typical Applications	Photocatalysts, electrochromic films, thin film deposition coatings, etc.

2. Hydrothermal method

Process principle

The hydrothermal synthesis method utilizes the special solubility and reactivity of water under high temperature and high pressure conditions to synthesize nano-tungstate powder with good crystallization and controllable morphology in a closed reactor.

The basic reaction framework is as follows:

(NH4) 10 [H2 W12 O42] +hot water→H2 WO4 · xH2 O ↓(nanocrystals)

Operation process

1. **Solution preparation** : Prepare a certain concentration of ammonium metatungstate solution and add a small amount of acid to adjust the pH to 1-3;
2. **Adding additives** : such as polyvinyl pyrrolidone (PVP), citric acid and other morphology-directing agents;
3. **High-pressure reaction** : Place in a Teflon-lined reactor, set the temperature to 120–200°C, and react for 6–24 hours;
4. **Cooling sampling** : After cooling to room temperature, filter, wash with water and dry;
5. **Post-treatment** : Mild calcination or surface modification as required .

Features and applicability

parameter	scope
Particle size	20–80 nm
Morphology	Rod, sheet, ball adjustable
Crystal form	Orthogonal/monoclinic H_2WO_4
Yield	＞90% (industrial test grade)

Excellent controllable morphology: adjustable temperature, reaction time and additives to finely control crystal growth;

degree of crystallization : suitable for optoelectronic functional materials with high requirements;

It can be scaled up moderately and is suitable for pilot plants.

3. Microemulsion method

Process principle

spatial confinement control of the nucleation and growth of tungstate by constructing a nano-reaction cavity with a stable oil-water interface. It is suitable for preparing tungstate nanoparticles with ultra-small particle size and high dispersion.
The reaction medium used is generally a three-phase system of water/oil/surfactant, for example:

- Oil phase: n-hexane, cyclohexane;
- Water phase: tungstate aqueous solution;
- Surfactants: CTAB, Span-80, Tween-60, etc.

In the W/O (inverse) system, the generation of tungstic acid is limited to the interior of the microemulsion droplets, achieving precise control of particle size.

Synthesis steps

1. Prepare tungstate aqueous phase (such as Na_2WO_4 solution) ;
2. Construct W/O reverse microemulsion system;
3. the acid phase (HCl microemulsion) to another microemulsion droplet ;
4. Stir evenly and react for several hours;
5. Tungstic acid nanoparticles were obtained by demulsification, extraction and washing;
6. Dry and spread if necessary.

Advantages and limitations

project	illustrate
advantage	Uniform particle size (5–20 nm), high dispersibility, and fine morphology control
shortcoming	Surfactant residues are difficult to completely remove; not easy to scale up; high cost
application	Ultrafine catalyst carrier, electronic grade tungstic acid intermediate, transparent conductive paste

4. Comparison of particle size and morphology control mechanisms

Technology	Particle size control method	Crystal morphology	Magnification
Sol-Gel Method	Hydrolysis rate, pH, aging time	Spherical/gel clusters	medium
Hydrothermal method	Temperature, time, type of additives	Flake/Rod/Spherical	good
microemulsion method	Microemulsion particle size and interface stability	Nearly spherical, amorphous nanoparticles	Higher difficulty

5. Functionalization direction and modification technology

In order to further improve the application performance of nano tungstic acid, the following modification technologies are usually combined:

- **Doping modification** : introducing Cu, Ag, Zn, Fe and other ions to improve conductivity and photocatalytic response;
- **Surface coating** : coating with SiO_2 , TiO_2 , and polymer to achieve interface stability and enhanced dispersion;
- **Heterostructure construction** : construct Z-type photocatalytic heterojunction with

gC_3N_4 , MoS_2 , etc.

- **Composite material integration** : Forming a conductive skeleton with carbon materials, graphene, etc., suitable for supercapacitor electrodes.

VI. Typical Industry Case: Development of Nano-tungstic Acid by CTIA GROUP

CTIA GROUP has successfully developed nano-tungstic acid products suitable for photocatalysis, self-cleaning coatings, electrochromic glass and other fields by establishing a three-in-one platform of high-purity tungstic acid precursors + controllable crystallization + surface regulation:

- The particle size was controlled at 20–40 nm using a hydrothermal-post-treatment combined route;
- Develop tungstic acid/PVP hybrid materials for conductive films;
- Establish a continuous hydrothermal reaction system to achieve stable supply of kilograms;
- Nano-tungstic acid products have been exported to research institutes and universities in Germany, Japan, Southeast Asia and other places.

VII. Summary

The preparation technologies of nano-tungstic acid are diverse and the mechanisms are complex, but through precise control of process parameters, multi-dimensional optimization of particle size, specific surface area, crystal form and functional performance can be achieved. Sol-gel method, hydrothermal method and microemulsion method each have their own advantages and are suitable for different stages of development from experimental research to pilot development. With the rapid development of low-carbon manufacturing and functional powders, nano-tungstic acid will become one of the irreplaceable functional core materials in the new material system.

3.4 Analysis of the Standard Preparation Process of Tungsten Acid Made by CTIA GROUP

a leading domestic tungsten-based inorganic chemical and functional powder material professional enterprise , CTIA GROUP has long been focused on the systematic research and development and large-scale production of tungstic acid and its derivatives. Through technology accumulation and engineering practice, the company has established a complete set of stable, environmentally friendly and efficient standard preparation processes for tungstic acid, covering APT, WO_3 , tungsten intermediate regeneration and other raw material paths, which are widely used in optical materials, tungsten salt intermediates , functional ceramics, electronic pastes and other fields.

This section takes the core process system of CTIA GROUP as an example to explain in detail its standard preparation process, key control nodes, quality management system and industrial practice results.

1. Overview of the process system

CTIA GROUP Tungsten Acid production system can be divided into three types of preparation paths:

Process route	Source of raw materials	Application
Route A	APT acid hydrolysis	High purity tungstic acid, electronic grade raw materials
Route B	WO_3 wet conversion method	Recycled material utilization, tungstate intermediates
Route C	Nano-tungstic acid synthesis method	Photocatalytic, electrochromic, electronic functional film materials

The three routes complement each other and together constitute an integrated production model of "standard + flexible + customized", with wide adaptability and customized delivery capabilities.

2. APT acid hydrolysis route standard process

Applicable to high purity tungstic acid and bulk general-purpose tungstic acid products
Main process steps:

1. **Raw material pretreatment**
   - APT screening, moisture determination;
   - Impurity detection (Fe, Si, Mo, P);
2. **Acid hydrolysis reaction**
   - Reaction parameters: HNO_3 concentration 1.5 mol/L, temperature controlled at 30–40°C;
   - Continuous stirring time: 60–90 min;
   - Agitation rate: 350–450 rpm;
3. **Sedimentation and aging**
   - The system pH was adjusted to 1.8–2.0;
   - Aging time ≥ 2 hours to prevent impurities from being carried;
   - Crystallization control : dynamic temperature control + molecular integration additives (patent number has been filed);
4. **Filtration and washing**
   - Multi-stage filtration;
   - Wash 3–5 times, end point conductivity ≤15 μS /cm;
   - The water reuse system is combined with the mother liquor acid regeneration station;
5. **Drying and crushing**
   - Vacuum and air-blast drying (80°C, 16 hours);
   - Mild air flow grinding process to ensure fluidity;
   - The finished product particle size D50 is controlled at 3–6 μm , and the sphericity is >0.9;
6. **Packaging and sampling**
   - Highly sealed PE bag packaging + argon sealed stainless steel barrel;
   - Three bottles are randomly sampled from each batch for physical and chemical index testing.

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3. Standard process of WO_3 conversion route

Applicable to the recovery of regenerated tungsten powder and preparation of industrial intermediates

1. **WO_3 powder classification and screening** ;
2. **Acid dissolution reactions** (HCl or HNO_3 , T = 70–85°C);
3. ** Adjust pH to precipitate tungstic acid (pH = 2–3);
4. **Aging + closed crystallization control technology (original module);
5. ** Filtration, cleaning and drying;
6. **Detect particle size, residual chlorine, tungsten content, and pH stability;

Note: The company uses the tungsten tailings recovery system to recycle WO_3 slag powder, with an annual conversion volume of up to 120 tons, significantly improving resource utilization and environmental benefits.

4. Nano-tungstic acid process system

Applicable to high-end functional materials (such as smart window films, self-cleaning ceramics)

- Core technology: low temperature hydrothermal + surfactant synergistic control + crystal regulation additives;
- Use multidimensional additives to control the crystallization path (PEG-400, PVP, etc.);
- Particle size control: D50 20–50 nm, specific surface area 80–110 m^2/g;
- Crystal form: regular flakes or spherical particles;
- Compatible with subsequent coating, compounding and loading processes;
- A closed dust-free reaction device is used to meet the cleanliness requirements of optoelectronic materials.

5. Quality Control System

CTIA GROUP implements a full-process quality traceability system, setting key quality control nodes from raw material storage to finished product delivery:

Test items	Process stage	Detection frequency	equipment
Impurity analysis (ICP-MS)	Raw materials/intermediates	Each batch	Agilent 7900
Particle size distribution	Finished Product	Each batch	Laser particle size analyzer (Malvern)
Crystal structure	Daily sampling	XRD	Bruker D8
Moisture content/crystallization water	Finished Product	Each batch	TGA-Q500
Fluidity and bulk density	Engineering Verification	3 days/time	Hall flow meter

The quality management system covers ISO 9001:2015 and the products comply with the EU RoHS/REACH directives, and an electronic material data labeling system (e-MSDS archive) has been established.

VI. Production capacity and market support

- **Production line scale** : 4 reaction lines + 2 drying/jet milling/packaging lines;
- **Designed capacity** : Annual output of tungstic acid products: 500 tons (including high-purity, functional and composite types);
- **Delivery capacity** : minimum order 1 kg, maximum monthly supply capacity 40 tons, with customer-customized production capabilities;
- **Export situation** : Products are exported to 15 countries and regions including Germany, India, Japan, Malaysia, South Korea, etc.
- **Data traceability** : Each batch of products is accompanied by an independent test report, number, certification number and ingredient traceability information.

VII. Summary of Features and Advantages

Advantages	Specific manifestations
Raw material source control	Own APT and WO_3 supporting raw material system to ensure stable supply
Process standardization	Full parameter solidification + intelligent instrument feedback control
Customer adaptability	The whole process including particle size, crystal form, coating, surface modification, etc. is adjustable
Strong compliance	Possessing MSDS, REACH, RoHS, ISO9001 and other certification systems
Environmental Compliance	Recycled water reuse, waste acid recovery, and nitrogen source treatment all achieve green closed loop

8. Summary

CTIA GROUP is a representative of an advanced process system with technical data as the core, product consistency as the goal, and customer diversity as the orientation. By building a high-purity, efficient, flexible, and environmentally friendly tungsten acid manufacturing platform, the company not only meets the demand for functional tungsten materials in the domestic and foreign high-end markets, but also provides stable support for the high-value utilization and sustainable development of tungsten resources .

Tungstic Acid Introduction
CTIA GROUP LTD

1. Tungstic Acid Overview

The tungstic acid (tungsten trioxide hydrate, $WO_3·H_2O$) produced by CTIA GROUP LTD is a high-purity yellow crystalline powder, manufactured using advanced precipitation and calcination processes. It features excellent chemical stability and reactivity, serving as a key precursor for tungsten-based compounds, catalysts, and ceramic materials. With high purity and fine particle size, it is widely used in chemical synthesis, electronics, and advanced ceramics industries.

2. Tungstic Acid Features

- Chemical Formula: $WO_3·H_2O$
- Molecular Weight: 249.85
- Appearance: Yellow crystalline powder
- Melting Point: Decomposes >100°C
- Density: 5.5 g/cm³
- Stability: Stable under dry conditions, decomposes in water to form tungstate ions, requires sealed storage
- Wide Applications: Used in catalyst preparation (selectivity >95%), tungsten oxide synthesis, ceramic pigments

3. Tungstic Acid Product Specifications

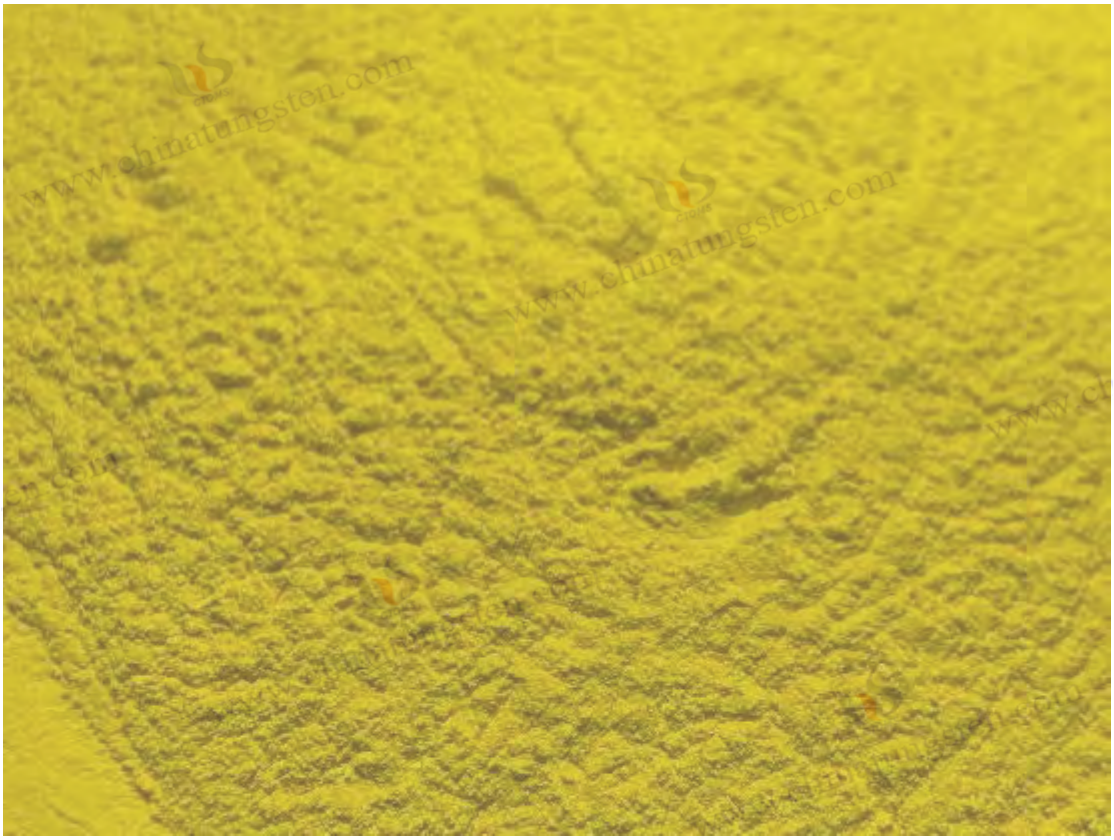
Grade	Purity (wt%)	Particle Size (μm)	Solubility	Impurities (ppm)
Reagent Grade	≥99.9	1–10	Slightly soluble	Fe≤10, Na≤5, Si≤10
Industrial Grade	≥99.5	1–10	Slightly soluble	SO_4^{2-} main, trace elements
Technical Grade	≥98.5	1–10	Slightly soluble	Minor oxide impurities allowed

4. Tungstic Acid Packaging and Quality Assurance

- Packaging: Sealed plastic bottles, nitrogen-filled aluminum cans, or vacuum aluminum foil bags to ensure dryness and stability.
- Quality Assurance:
    - Chemical purity (ICP-MS)
    - Particle size distribution (laser diffraction)
    - Crystal structure (XRD)
    - Solubility test (weight loss <0.1% in water)

5. Tungstic Acid Procurement Information

- Email: sales@chinatungsten.com
- Phone: +86 592 5129595
- Website: http://tungstic-acid.com



Chapter 4: Characterization Technology and Detection Methods of Tungstic Acid

4.1 XRD crystal form and crystal plane analysis

X-ray Diffraction (XRD) is a core technology used to analyze the crystal structure and phase composition of materials. In the research and industrial preparation of tungstic acid materials, XRD is not only used to identify its crystal form (such as monoclinic, orthorhombic, polymorphic, etc.), but also can assist in analyzing the transformation behavior of tungstic acid under different conditions, the direction of crystal growth, and the doping of impurities.

Since the structure of tungstic acid is closely related to its physicochemical properties, crystal analysis becomes a key step in controlling product quality, guiding process regulation, and optimizing downstream application performance.

1. Overview of technical principles

The basic principle of XRD is based on Bragg's Law:

nλ =2dsin θ n\lambda = 2d\sin\ thetanλ =2dsinθ

in:

- nnn is the diffraction order;
- λ\ lambdaλ is the incident X-ray wavelength (usually 1.5406 Å, Cu Kα);
- ddd is the interplanar spacing;

- θ\ thetaθ is the angle of incidence/angle of diffraction.

When X-rays are irradiated to a crystal sample, different crystal planes will reflect at specific angles to form diffraction peaks. By recording the relationship between intensity and angle, a diffraction pattern can be constructed to determine the crystal type and orientation.

2. Typical crystal forms and XRD characteristics of tungstic acid

Tungstic acid can form the following main crystal forms under different preparation methods and heat treatment conditions:

Crystal form	Crystal system	Common conditions	XRD characteristic peak position (2θ, Cu Kα)
Orthorhombic	α - H_2WO_4	APT acid hydrolysis low temperature precipitation	18.3°, 23.4°, 28.6°, 34.1°
Monoclinic	β - H_2WO_4	Heat dried product	22.8°, 24.2°, 29.7°, 36.3°
Amorphous	-	Rapid precipitation/cooling	There is no obvious sharp peak in the XRD spectrum, only a broad diffuse band
Metastable Polycrystalline	Non-standard structure	Nanosynthesis Path	Low intensity and broad peaks appear and need to be compared with the standard spectrum

Note : The different number of water molecules in tungstate hydrate will also cause slight changes in the crystal structure and a slight shift in the XRD peak position.

3. Sample preparation method

High quality XRD data depends on good sample preparation. Tungstic acid sample preparation requires special attention to prevent crystal transformation and sample agglomeration.

Here are the steps:

1. **Drying** : Dry the tungstic acid sample at 60–80°C for 6–12 hours to remove free water;
2. **Grinding** : Grind lightly in an agate mortar to control the particle size within 1–5 μm ;
3. **Spreading** : Take about 50 mg of powder and press it evenly in the sample loading tank. The surface should be as smooth as possible without holes.
4. **Controlled environment** : If analyzing hydrated structures, it is recommended to measure quickly under humidity-controlled conditions to avoid structural changes;
5. **Other requirements** : Make sure the sample has no magnetic, conductive contamination or surface oxidation.

4. Device parameter settings and scanning strategies

parameter	Recommended value	illustrate
X-ray Source	Cu Kα (λ = 1.5406 Å)	Common wavelengths
Scan range	2θ = 5°–80°	Covering the main peak range
Step Length	0.02°	Balancing speed and resolution
Scan speed	1–2°/min	Keep peak shape intact
Working voltage/current	40 kV / 30 mA	Standard analysis mode
model	θ–2θ scan	Keep the sample surface normal and incident light fixed

If you are interested in the preferred orientation of the crystal plane, you can further use pole figures or Rietveld analysis to obtain quantitative information.

V. Results Analysis and Typical Cases

Case 1 : Preparation of tungstic acid sample by APT acid hydrolysis

- Sample process: APT + HNO_3 → H_2WO_4 (low temperature precipitation)
- The XRD spectrum shows characteristic peaks at 18.3°, 23.4°, and 28.6°, corresponding to orthorhombic H_2WO_4 ;
- The peak shape is sharp, there are no impurity peaks, and the crystal form is pure, indicating that the reaction is complete and the crystal growth is sufficient;
- Compares to JCPDS card #08-0450.

Case 2: Preparation of tungstic acid sample by conversion of WO_3

- Process conditions: WO_3 wet acid hydrolysis + aging and drying
- There are three peaks at 22.8°, 24.2°, and 29.7° in the spectrum, which are inferred to be monoclinic H_2WO_4 ;
- Accompanied by a weak 22.1° peak, there may be incompletely converted WO_3 residues .

Case 3: Nano-tungstic acid sample

- Prepared by hydrothermal method;
- The peak position broadens significantly , and the main peak intensity decreases;
- The grain size was calculated (Scherrer formula) to be approximately 15–25 nm;
- Conclusion: It is nano-H_2WO_4 in quasi-crystalline state . The crystal form is retained but the size effect is obvious.

VI . Industrial Application and Quality Judgment Standards

CTIA GROUP uses XRD as one of the core quality control indicators of tungstic acid products, mainly to judge the following:

- **Crystal purity** : determine whether it is the target crystal form (such as orthorhombic/monoclinic);
- **Crystal consistency** : compare peak position and intensity of different batches;
- **Relative crystallinity** : Analyze the crystal quality of powder by main peak area;
- **Impurity detection** : detection of APT, WO_3 or non-target crystal contamination;
- **Particle size estimation** : Nano-sized tungstic acid products need to use the Scherrer formula to calculate the particle size.

According to industrial standards, the crystal purity requirement is ≥95%, the peak position shift is ≤±0.2°, and there is no secondary crystal phase as a qualified product requirement.

4.2 FTIR and Raman spectroscopy studies

Fourier transform infrared spectroscopy (FTIR) and Raman spectroscopy (Raman) are two complementary molecular vibrational spectroscopy techniques that are widely used to analyze chemical bond characteristics, functional group existence forms, molecular symmetry and crystal structure in inorganic materials. For tungstic acid (H_2WO_4) and its derivatives, these two spectral techniques can not only reveal its basic W–O bonds, W=O double bonds and vibration modes of structural units, but also be used to determine its hydration state, degree of polymerization and doping effect.

This section will combine the actual sample spectra to elaborate on the operation methods, typical characteristics and engineering significance of FTIR and Raman in tungstic acid research.

1. Basic principles

FTIR principle

FTIR is based on the infrared light absorption phenomenon caused by molecular vibration. When the covalent bonds in the sample undergo stretching or bending vibrations, if their dipole moments change, they can absorb infrared light of a specific frequency, thereby producing an infrared absorption peak.

Commonly used for analysis:

- Bond types: W–O, O–H, H–O–H;
- terminal oxygen/bridging oxygen structure in tungstate ions ;
- Hydration structure changes.

Raman Principle

Raman spectroscopy relies on the change in polarizability caused by molecules during the scattering process. When monochromatic laser light irradiates molecules, most of the light is elastically scattered (Rayleigh scattering), and a small part of the light is inelastically scattered due to molecular vibration, which is Raman scattering.

Applies to:

- Inorganic ions with strong symmetry (such as $[WO_6]$) vibrate;
- Crystal symmetry and stress state analysis;
- metal oxygen clusters (especially multi-nuclear systems such as polytungstate).

FTIR and Raman are complementary in information. FTIR is more sensitive to dipole changes, while Raman is more sensitive to symmetric stretching and skeleton vibration.

2. Sample preparation and test conditions

FTIR sample preparation:

Way	illustrate
KBr tablet method	Mix the sample with dry KBr powder at a ratio of 1:100 and press into a pellet; suitable for the mid-infrared region (400–4000 cm^{-1})
ATR direct method	Small samples directly contact the ATR crystal, suitable for rapid analysis and surface detection
Gas phase/solution state	Generally not suitable for tungstic acid due to its high thermal stability and poor solubility

Test recommendations: Sampling volume > 1 mg, dry the sample to avoid interference with CO_2 and H_2O absorption .

Raman sample preparation:

Way	illustrate
Powder method	Spread the dried sample directly on the glass slide and press it with a needle
Laser source	Commonly used 532 nm or 785 nm lasers (to avoid sample fluorescence)
power	Controlled at 5–20 mW to avoid burning samples or photodegradation
Integration time	10–30 s, scan range 100–1200 cm^{-1}

Note: High power can easily cause thermal drift, and tungstate hydrate can easily lose water and denature under high energy excitation.

3. Typical FTIR spectral characteristics of tungstic acid

Main absorption section (taking KBr tablet as an example):

Wavenumber range (cm^{-1})	Vibration response	Features
3400–3600	–OH stretching vibration	O–H bond in hydrated tungstic acid; can reflect the degree of hydration
1600–1650	H–O–H variable angle vibration	Hydrogen bonding between hydrated molecules
890–970	W=O terminal oxygen stretching vibration	Typical strong absorption , the intensity is related to the number of W=O
700–850	W–O–W bridge oxygen vibration	It is related to the polymer structure and crystal form. Position shift reflects the change of crystal form.
＜600	W–O Bending and rocking vibrations	Structural skeleton, often with multiple peaks superimposed

Spectrum parsing example:

- **Sample: Strong peaks of tungstic acid prepared by APT acid hydrolysis**
  appear at 890, 735, and 610 cm^{-1} , representing typical orthorhombic H_2WO_4 ;
- **Sample: After drying, the –OH band of tungstate powder**
  is significantly weakened, and the W=O absorption is enhanced, indicating that the hydration structure is reduced;
- **Sample: The W–O peak position of Cu-doped tungstate**
  shifts to lower wavenumbers, indicating structural expansion and lattice softening.

4. Typical Raman spectral characteristics of tungstic acid

Raman spectrum can more clearly distinguish the crystal structure and degree of polymerization, especially for polyanion systems such as polytungstate and heteropolyacid.

Main feature section:

Wavenumber range (cm^{-1})	Vibration response	meaning
850–1000	W=O tensile vibration	terminal oxygen in the crystal structure , the stronger the peak
700–800	W–O–W bridge oxygen vibration	The polymer structure and crystal plane arrangement have a significant impact
400–600	W–O bend	Crystalline skeleton integrity performance area
<300	Lattice vibration	Mostly used for doping and crystal defect detection

Typical spectrum comparison:

- **Nano-tungstic acid vs. micro-tungstic acid**
  nanopowder The peak position is broadened, indicating that the lattice distortion and size effect are significant;
- **Polymer metatungstate vs monomer H_2WO_4 The former**
  shows multiple thin peaks at 700–800 cm^{-1} , representing a higher-order structure (such as Keggin type);
- **of the tungstic acid samples with different heat treatments ,**
  the sharper the W=O peak in the spectrum , indicating that the crystal order is improved.

5. Engineering value of complementary use of FTIR and Raman

Application Target	FTIR contribution	Raman Contributions
Determining hydration level	Clarify the changes in the O–H and H–O–H regions	Insensitive to water; suitable for dry powder
Identification of structural type	Identify W=O and W–O–W bond types	Clarify degree of polymerization and symmetry
Crystal form identification	Limited Capacity	Can assist in identifying lattice strain and phase transitions
Impurity detection	Sensitive to organic residues	Sensitive to doped metal oxides

For example, in the production process of CTIA GROUP , FTIR is used to quickly determine whether the hydrated tungstic acid is dried to the required standard, while Raman is used to determine whether there is crystal structure distortion or incompletely reacted raw material residue.

VI. Common Problems and Precautions

question	Possible causes	Suggested Actions
Absorption peak tailing is serious (FTIR)	The sample contains a lot of water and the background is unstable	Dry thoroughly using dry KBr
Low intensity of Raman peak	The laser power is too small or the focus is inaccurate.	Check the excitation conditions and focus status

Peak position drift	Temperature drift or instrument calibration problem	Calibrate the instrument and maintain a constant temperature environment
FTIR cannot distinguish crystal forms	Crystal symmetry close to	Combined with XRD or Raman to further confirm

VII. Summary

FTIR and Raman spectroscopy are important tools for analyzing the molecular structure, functional group state, degree of polymerization and degree of crystallinity of tungstic acid. Both have their own advantages, and combined use can achieve multi-dimensional analysis of tungstic acid samples from chemical bonds to lattice structures. By establishing a standard peak position database and spectrum comparison system, it can provide strong data support for the research and development, quality control and engineering optimization of tungstic acid materials.

4.3 SEM/TEM micromorphology observation

Tungstic acid (H_2WO_4) is an inorganic acid with complex structure and diverse crystal forms. Its microscopic morphology not only reflects the material preparation process and crystal growth behavior, but also directly affects its performance in applications such as catalysis, coating, electronics, and energy conversion. Therefore, detailed microscopic morphology observation and structural analysis of tungstic acid powder using scanning electron microscopy (SEM) and transmission electron microscopy (TEM) has become an essential means for basic research and industrial quality control.

This section will systematically introduce the operation process, structural characteristics, typical images and characterization value of SEM and TEM in tungstic acid samples.

1. Brief description of technical principle

Scanning electron microscopy (SEM)

SEM scans the sample surface by focusing an electron beam and detecting secondary electron or backscattered electron signals to obtain the sample's surface morphology image. Its resolution can generally reach below 10 nm, which is suitable for observing information such as particle size, morphology, agglomeration behavior and surface roughness.

Transmission electron microscopy (TEM)

TEM uses a high-energy electron beam that penetrates the sample to form an image on a fluorescent screen or CCD. Its resolution can reach sub-nanometer or even picometer levels , and it can observe lattice fringes, atomic arrangement, phase interface, defects and nanocrystalline structure.

2. Sample preparation method

SEM sample preparation:

1. **Sampling** : Weigh dry tungstic acid powder (about 5–10 mg);
2. **Dispersion** : Add a small amount of ethanol and disperse ultrasonically for 3-5 minutes;

3. **Sample loading** : drop the dispersion onto the conductive carbon glue and air dry or vacuum dry at low temperature;
4. **Coating (if necessary)** : If the sample has poor conductivity, it can be coated with gold or carbon film (thickness about 5–10 nm) to prevent electron beam accumulation.

TEM sample preparation:

1. **Ultrasonic dispersion** : Disperse the powder with ethanol and sonicate for 10 minutes;
2. **Drop film** : Take a small amount of dispersion and drop it on the copper mesh (carbon film support);
3. **Drying** : Natural drying or removal of solvent under vacuum;
4. **Sample thickness requirement** : particle size ≤100 nm is preferred, and ultrafine powder is more suitable for TEM observation.

3. SEM Characterization Content and Typical Images

Typical applications of SEM in the characterization of tungstic acid materials include:

- Observe **the particle morphology** : such as needle-shaped, flake-shaped, rod-shaped, cluster-shaped, and spherical;
- Determine **the degree of crystallinity** : highly crystalline samples have sharp edges, while low crystalline or amorphous samples have fuzzy surfaces;
- Analyze **particle size and distribution** : Combined with image analysis software, the particle D50 and distribution range can be counted;
- Probing **Agglomeration and Pore Structure** : Understand sample surface area and secondary particle morphology.

Example:

1. **APT acid hydrolysis of tungstate samples**
   - SEM images show regular short rod-shaped crystals;
   - The average length is about 1–2 μm and the width is about 300–600 nm;
   - The crystals have clear edges and smooth surfaces, indicating good crystallization.
2. **Hydrothermal Synthesis of Nano-tungstic Acid**
   - A large number of spherical particles appeared, with a diameter of about 50–100 nm;
   - Some agglomeration may be related to the drying process;
   - The porous surface structure can be seen in the high-magnification image, which helps to form active sites for catalytic reactions.
3. **WO_3 conversion to tungstate**
   - SEM showed a lamellar stacked structure;
   - The surface is rough, the particles are closely connected, and they are in a layered flocculated state;
   - Mostly used as coating material precursor.

TEM structure observation and lattice analysis

In addition to morphological observation, TEM is more important for high-resolution structural and crystal information analysis, including:

- Crystal defect observation;
- Interplanar spacing measurement;
- Crystal direction judgment;
- of impurities or coatings;
- Selected area electron diffraction (SAED) spectrum analysis.

Typical observations:

1. **Nano-tungstic acid crystal structure**
    - HRTEM images show clear lattice fringes;
    - The measured interplanar spacing d = 0.378 nm matches the orthorhombic phase H_2WO_4 (200) plane;
    - The grain size is about 30–50 nm, and the edges are smooth, indicating that the particles are regular;
2. **Amorphous tungstate nanoclusters**
    - No regular lattice fringes are seen in the image, which appears as a disordered diffuse outline;
    - The SAED pattern is a diffuse ring, confirming that the sample is amorphous or has low crystallinity;
3. **Observation of doped tungstate crystals**
    - Slight lattice distortion is observed after Cu doping;
    - The lattice fringes are bent and dislocation defects appear locally;
    - Provide a microscopic basis for regulating electrical properties by doping.

5. Image Analysis and Quantitative Measurement

Combined with image processing software such as ImageJ, SEM/TEM images can be analyzed as follows:

Analyze Project	Contents
Particle size measurement	Manually or automatically extract edges and generate parameters such as D50, D90, etc.
Shape recognition	Classify particle shape, such as sphericity, flattening, etc.
Distribution Statistics	Histogram analysis of particle size distribution uniformity
Interplanar spacing	Calculate the lattice d value and confirm the crystal plane properties in combination with XRD
Defect Identification	Identification and counting of defects, holes, and edge imperfections

These data can be further used for quality control, process optimization and product performance prediction.

6. Error sources and common problems

question	Cause Analysis	Suggested Solutions
Severe reunion	Insufficient dispersion or uncontrolled drying	Add dispersant and optimize ultrasonic time
Blurred image	Charge accumulation or misfocus	Surface coating or adjusting working distance
TEM image is not clear	Sample thickness is too large	Particle size reduction or centrifugal classification
Lattice fringe ghosting	Sample drift and vibration effects	Use a low temperature or stable sample platform

7. Engineering Applications in Tungstic Acid Research

In the R&D and quality control system of CTIA GROUP, SEM and TEM are widely used in the following scenarios:

- **Evaluate the effect of the preparation process** : the effect of different acid hydrolysis paths, temperatures, and pH on crystal morphology;
- **Development of functionalized tungstic acid** : observation of coating thickness and nanocrystalline core distribution;
- **Analyze failure mechanisms** : crystal cracking and pore changes caused by aging, sintering, etc.
- **Auxiliary particle size classification process design** : linked with laser particle size analysis to achieve full particle size coverage detection.

In addition, the coordinated analysis of morphology and crystal form (such as XRD+SEM+TEM) is an important means to determine whether high-purity tungstic acid can meet the requirements of downstream high-end applications.

8. Summary

SEM and TEM techniques provide powerful tool support for the microstructure analysis of tungsten acid materials. The former focuses on surface morphology and particle characteristics, while the latter focuses on internal structure and lattice information. Through the complementary use of the two, not only can the preparation process and quality control be optimized, but also a solid morphological foundation can be provided for the high-performance development of tungsten acid in the fields of energy materials, optoelectronic devices, functional coatings, etc.

4.4 TG-DSC thermal analysis

TG (Thermogravimetric Analysis) and DSC (Differential Scanning Calorimetry) are key analytical techniques for studying the thermal behavior of tungstic acid. Tungstic acid (H_2WO_4) is particularly suitable for comprehensive research using TG-DSC due to its high hydration characteristics, thermosensitive crystal transformation, and sensitivity to high temperature conditions.

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This section will introduce in detail the basic principles of TG-DSC, sample behavior, thermal decomposition pathways, parameter interpretation, and practical applications in process design and quality control.

1. Overview of technical principles

TG principle

TG technology analyzes the decomposition, oxidation, volatilization or desorption of substances by measuring the mass change of samples under programmed temperature (or constant temperature) conditions.

Tungstic acid undergoes multiple mass loss stages during heating, which are mainly related to the release of water and the transformation of oxidation states .

DSC Principle

DSC measures the change in heat absorbed or released by the sample during heating/cooling. Combined with TG, it can be judged:

- Whether the dehydration reaction is endothermic or exothermic;
- The onset and peak temperature of the crystal transformation;
- Formation temperature and thermal stability range of tungstic acid decomposition products.

The combination of TG and DSC can not only give the "quantitative change" of thermal behavior , but also reveal its "reaction mechanism".

2. Sample preparation and test conditions

Sample preparation tips:

- **Sample type** : dry tungstic acid powder (purity ≥99%, particle size 1–10 μm);
- **Sample mass** : about 5–10 mg, evenly spread in the crucible;
- **Crucible type** : platinum crucible (high purity and pollution-free), ceramic crucible (economical and heat-resistant);
- **Environmental atmosphere** :
  - Nitrogen (inert atmosphere) or air (oxidizing environment);
  - Gas flow rate 50–100 mL/min;
- **Heating rate** : 5–10°C/min (adjustable according to reaction intensity);
- **Temperature range** : usually from room temperature to 800°C, some samples can be extended to 1000°C.

3. Typical TG-DSC behavior and decomposition path of tungstic acid

Stage division and behavior description:

Temperature range	Mass change (TG)	Thermal behavior (DSC)	Reaction Description
30–120°C	Slight mass loss (2–3%)	Endothermic Fluctuation	Desorption of physically adsorbed water
120–250°C	5–10% loss in quality	Gentle endothermic peak	Partial structural water release
250–400°C	10–20% loss in quality	Obvious endothermic peak	The main crystal water is completely released, $H_2WO_4 \rightarrow WO_3 \cdot xH_2O$

400–600°C	Small quality fluctuation or stable	Slow heat release	Crystal transformation, lattice rearrangement
＞600°C	The quality remains basically unchanged	No obvious thermal effect	Forming a stable tungsten trioxide (WO_3) structure

Note: Fully hydrated H_2WO_4 → The theoretical mass loss of WO_3 is about 18–21%, which can be used to estimate the degree of hydration of the sample.

4. TG-DSC curve analysis example

Sample 1 : Tungstic acid obtained by APT acid hydrolysis

- **TG curve** :
  - The initial weight loss section is at 50–150°C, accounting for 2–3% of the total sample mass;
  - The main dehydration stage was at 150–350°C, with a cumulative weight loss of about 14.5%;
- **DSC curve** :
  - A clear endothermic peak appears at 150–170 °C, corresponding to the removal of crystal water;
  - After 360°C, there is a small exothermic fluctuation, which is inferred to be lattice rearrangement;
- **Conclusion** : The sample is a highly hydrated form of $H_2WO_4 \cdot xH_2O$, which stably transforms to WO_3 at about 400–600°C.

Sample 2: Microcrystalline Nanotungstic Acid

- **TG** : The overall weight loss distribution is relatively uniform, and the main weight loss section is 80–250°C;
- **DSC** : Broad endothermic peak, indicating that the hydration structure is relatively disordered;
- **Note** : The particles are small and the surface area is large, so it is difficult to distinguish between structured water and surface water.

5. Study on the mechanism of thermal decomposition reaction

TG-DSC data can be used to establish the following reaction process model:

1. **Physical adsorption water desorption** :

H2WO4 · xH2O → H2WO4+xH2O ↑

Endothermic process, the quality decreases slowly.

2. **Removal of crystal water and lattice rearrangement** :

H2WO4→WO3 · yH2O+H2O↑

3. **Final dehydration and WO_3 formation** :

WO3 · yH2O → WO3+yH2O ↑

The process can be kinetically analyzed by model fitting (such as Coats-Redfern, Ozawa-Flynn-Wall) to obtain the activation energy Ea , reaction order n and other thermal decomposition kinetic parameters.

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VI. Industrial Application and Engineering Significance

In the production and quality control system of CTIA GROUP Tungsten Acid series products, TG-DSC is mainly used for:

- **Determine the hydration status of the product** : infer the hydration structure and storage stability based on the weight loss curve;
- **Set the drying temperature window** : prevent overheating from causing crystal damage or premature reaction;
- **Optimize heat treatment process** : such as WO_3 thermal reduction and tungstic acid calcination temperature control;
- **Screening material suitability** : to adapt pre-treatment temperature for different downstream applications (such as slurry, electrode materials);

For example, in the production of coating tungstate slurry, the calcination temperature is required not to exceed 400°C in order to retain a certain amount of structural water and enhance the bonding and conductivity properties.

7. Precautions and error control

question	Possible causes	Suggested Actions
Weightlessness curve platform is unstable	Sample humidity is not controlled or powder is not uniform	Dry the sample and repeat grinding
DSC baseline drift	Insufficient thermal balance of the instrument	Preheat the empty sample and reset to zero
Mass loss exceeds theoretical value	Organic impurities or side reactions	Improve purity, add DSC reference material
Poor repeatability	Uneven sampling	Increase sampling volume and improve mixing uniformity

8. Summary

TG-DSC thermal analysis is a key tool for evaluating the thermal stability, decomposition path, crystal transformation and water content of tungstic acid. The synergistic information of quality and thermal effect provided by it can be used in multiple links such as raw material analysis, process optimization, thermal treatment process setting and product safety assessment. The establishment of standard curve and thermal weight loss database has important strategic value for the quality control of tungstic acid throughout its life cycle.

4.5 XPS surface element valence analysis

X-ray Photoelectron Spectroscopy (XPS) is a non-destructive, highly element-selective and sensitive surface analysis technique. It measures the kinetic energy of photoelectrons excited from the surface of the material and infers their binding energy, thereby identifying the presence, chemical state and valence changes of each element. In tungstic acid (H_2WO_4) and its derivative systems, XPS is mainly used to analyze the chemical valence state of tungsten (such as W^{6+} , W^{5+}), the binding form of oxygen (O^{2-} , OH^- , structural water, etc.), the state of impurity ions (such as Cu^{2+} , Na^+ doping) and surface modification effects.

This section will introduce in detail the theoretical basis, sample preparation, peak shape analysis and practical application of XPS, and illustrate it with typical data of China Tungsten Intelligence in tungstic acid material analysis.

1. Overview of XPS Technology Principles

When X-rays irradiate the surface of a sample, electrons in the inner orbits of atoms in the material may absorb photon energy and jump out to become photoelectrons. The relationship between their kinetic energy (KE) and binding energy (BE) is as follows:

$BE = h\nu - KE - \phi$

in:

- hvh \ nuhv is the photon energy of the incident X-ray (usually Al Kα line, 1486.6 eV);
- ϕ \ phi ϕ is the work function of the photoelectron analyzer;
- BE is the binding energy, which is the binding strength between electrons and atomic nuclei, and is affected by the type of element and the chemical environment.

Different elements, different valence states, and different chemical environments will show specific binding energy peak positions and satellite peak characteristics.

2. Sample preparation and test parameters

Sample requirements:

condition	Request Description
Dry state	The powder must be completely dry to avoid evaporation of structural water affecting the vacuum system
Uniform particles	The recommended particle size is ≤10 μm to prevent thick layer shielding effect.
No volatile matter	Contains no precipitable organic residues or low temperature desorption products
Sample loading	Press the powder evenly onto the conductive tape or special sample slot, compact it and make the surface flat.

Test parameters:

project	Recommended settings
light source	Al Kα（1486.6 eV）
Resolution	High resolution mode (0.1 eV/step)
Scan area	0–1200 eV (full spectrum), W4f/O1s focused
Pharmaceutical environment	High vacuum (10^{-9} mbar level)
Neutralization system	Low energy electron beam neutralization to suppress charge accumulation

3. Peak position and valence state indication of main elements in tungstic acid

1. W elements (W4f zone)

W^{6+} is the most common valence state in tungstic acid, and its XPS spectrum usually shows two clear main peaks in the 35-40 eV region:

track	Peak position range (eV)	illustrate
W 4f $_{7/2}$	35.5–36.0	Main peak, higher intensity
W 4f $_{5/2}$	37.5–38.0	Sub-peaks, with a spacing of about 2.1 eV

- **Pure H_2WO_4 : shows two symmetrical** peaks with concentrated peak positions, indicating that W^{6+} has a single valence state **;**
- **Doped samples** : If there are W^{5+} or W^{4+} components, W 4f $_{7/2}$ will show a shoulder or additional peak between 34.0–35.0 eV.

2. O element (O1s zone)

The O 1s spectrum can be divided into three common peaks, corresponding to oxygen atoms in different chemical environments:

Peak position (eV)	distribute	Chemical environment
530.0–530.5	Lattice O	Lattice oxygen (W=O, W–O–W)
531.5–532.0	Surface OH	Hydroxyl or adsorbed water
532.5–533.5	H_2O molecule /carbonate	Water or environmental pollution sources

The change in the intensity ratio of the O1s spectrum can reflect information such as the sample's hydration state, surface hydroxyl density, and cleanliness level.

3. Impurities and doping elements (Na, Cu, P, etc.)

- Na 1s: about 1071 eV;
- Cu 2p: 932.5–935.5 eV (Cu^{+} is distinguishable from Cu^{2+});
- Cl 2p: 198–200 eV (Cl^{-} residue identification);
- Mo 3d: 229–233 eV (checked by impurity Mo doping).

The impurity content, doping level and chemical state can be obtained together through full spectrum scanning.

4. Data interpretation and graph analysis cases

Sample A: Standard APT acid hydrolysis of H_2WO_4

- W 4f spectrum: double peaks at 35.8 eV and 37.9 eV, consistent with the W^{6+} characteristics;
- O 1s spectrum: main peak at 530.4 eV (lattice oxygen), secondary peak at 532.0 eV (surface OH);
- $^{5+}$ or metallic tungsten were detected .

Sample B: WO_3 wet method to prepare tungstic acid sample

- peak in the O 1s spectrum is relatively strong;
- A slight peak at 533 eV is visible, which is presumed to be adsorbed water;
- XRD showed that the crystal form was slightly non-ideal, and XPS confirmed that the surface activity was high and the degree of hydration was strong.

Sample C: Cu-doped tungstate

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- Cu 2p $_{3/2}$ is located at 933.2 eV with a satellite peak, which is confirmed to be Cu^{2+};
- The W 4f peak position shifts to lower energy by 0.3 eV, indicating a redistribution of lattice electrons;
- The O1s spectrum width increases, indicating a change in the hydroxyl environment.

5. Quantitative analysis and chemometric calculation

Element atomic ratio analysis can be performed using peak area and sensitivity factor:
Atomic Ratio=IB / SB IA / SA

Where III is the peak area and SSS is the element sensitivity factor.
For example:

- If the W:O atomic ratio is close to 1:4, it can be confirmed as a standard H_2WO_4 structure;
- If the surface O content is high (O/W>4.5), it may contain structural water or hydroxyl groups;
- If a low-valence peak appears on the W peak after doping, the number of doping transfer electrons can be estimated.

6. Surface modification/coating evaluation

XPS is particularly suitable for studying tungstic acid surface-coated modified materials, such as:

- **SiO_2 coated tungstic acid** : Si 2p peak can be observed (about 102–104 eV);
- **Organic ligand modification** : C 1s spectrum shows chemical bond peaks such as C–O, C=O, and COOH;
- **Graphene - loaded tungstic acid** : Enhanced sp^2/sp^3 component resolution and D/G ratio change in C 1s;

through deep layer exfoliation or Ar^+ ion etching.

7. Application Cases of XPS Data in CTIA GROUP

In the development of high-end tungsten acid materials of CTIA GROUP , XPS is widely used in the following fields:

Application	Analysis objectives	Examples of achievements
Development of high purity tungstic acid	Verify the purity and impurity types of W^{6+}	W^{6+} ratio> 99 %, no W^{5+} shoulder
Doping material design	Determine doping valence and distribution uniformity	Clear control of valence state of Cu^{2+} and Ag^+ doped samples
Evaluation of coating functional layer	Surface Si/P/N and other element bonding methods	The C/O/P ratio on the surface of the film-forming tungstic acid sample is clear
Process quality assessment	Cl^- and Na^+ after cleaning	The adsorption peak in O1s is weakened and the cleanliness meets the standard

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8. Summary

XPS technology provides key information support for the surface structure, chemical state, doping mechanism and interface reaction of tungstic acid. Through in-depth analysis of W 4f, O 1s and impurity spectra, it can achieve a full range of characterization from structure verification to quantitative determination, from defect identification to film formation control. It has irreplaceable and important value in building a high-performance tungstic acid- based material system, ensuring the quality stability of industrial products, and supporting the research of tungsten chemical systems.

4.6 Specific surface area and pore structure (BET analysis)

Specific surface area and pore structure are important indicators that determine the physical properties and application effects of tungstic acid powder materials, especially in photocatalysis, electrode materials, gas sensors, adsorbents and surface reaction systems. BET (Brunauer -Emmett-Teller) method is a standard method for evaluating the surface area of materials. Combined with BJH (Barrett-Joyner- Halenda) or DFT (Density Functional Theory) and other analytical methods, the pore size distribution, pore volume and pore type of the material can be further analyzed.

This section will introduce in detail the BET technical principles, sample testing, typical data analysis of tungstic acid and engineering application scenarios to help readers fully understand the relationship between specific surface area and the microstructure regulation and functional performance of tungstic acid materials .

1. Overview of technical principles

The BET method is based on the principle of physical adsorption. It measures the total amount of gas that can be adsorbed per unit mass of sample through the process of forming a monomolecular layer of inert gas (such as nitrogen) on the solid surface at low temperature, thereby calculating the specific surface area (m^2/g) of the material.

Core equation:

$$\frac{1}{v[(P_0/P)-1]} = \frac{c-1}{v_m c} \cdot \frac{P}{P_0} + \frac{1}{v_m c}$$

in:

- vvv : adsorbed gas volume;
- vmv_mvm : volume required for monolayer adsorption;
- P/P0P/P_0P/P0 : relative pressure;
- ccc: constant, reflecting the adsorption potential;
- Specific surface area SSS: calculated from vmv_mvm and the cross-sectional area of adsorbed gas molecules.

The pore volume, pore size distribution and pore structure type can also be obtained through isothermal adsorption/desorption curves.

2. Sample preparation and testing process

Sample requirements:

condition	Require
Dry state	No structural water and adsorbed water, moisture content <0.5%
Powder particle size	1–20 μm is appropriate to avoid large particles affecting the desorption rate
Quality requirements	≥100 mg (general analysis), ≥300 mg (pore size distribution)
No volatile impurities	Avoid organic residues interfering with adsorption behavior

Pre-treatment process:

- **Degassing** : vacuum treatment at 120–200°C for ≥4 hours to remove gas and moisture;
- **Cooling** : After cooling to room temperature, conduct adsorption test;
- **Analysis gas** : commonly used nitrogen (N_2), the measurement temperature is 77 K (liquid nitrogen environment);
- **Relative pressure range** : usually set between $P/P_0 = 0.05 – 0.3$ for BET fitting.

3. Data analysis: specific surface area, pore diameter, pore volume

1. Specific surface area (BET surface area)

	BET area range (m^2/g)	Features
Micron - sized H_2WO_4	2–10	Low surface roughness, mainly the gaps between particles
Nano H_2WO_4	20–60	Smaller particle size leads to higher external surface area
Pore structure control samples	60–150	The appearance of microporous/ mesoporous structure is conducive to adsorption and diffusion

2. Pore structure

- **Total pore volume** : the volume of gas that can be contained per gram of sample (cm^3/g), usually in the range of 0.01–0.5;
- **Pore Size Distribution** :
  - Micropores (<2 nm);
  - mesoporous (2–50 nm);
  - macropores (>50 nm);
- **Commonly used models** :
  - The BJH method is suitable for mesopore analysis;
  - The DFT method is suitable for high-resolution analysis of microporous structures;
  - NLDFT is suitable for complex mixed pore systems.

3. Adsorption/desorption isotherm type (IUPAC classification)

type	feature	Applicable instructions

Type I	Microporous material, quickly saturated	This indicates that the material has a high-energy microporous structure.
Type II/III	Non-porous materials	More common in coarse powders with large particle size and low porosity
Type IV	The presence of hysteresis loops indicates a mesoporous structure	Most commonly found in functional tungstate powders
Type V/VI	Special surface adsorption behavior	This indicates that the surface active centers are uneven or multiply distributed.

4. BET analysis case of typical tungstic acid samples

Sample 1 : APT acid hydrolyzed tungstic acid (micrometer level)

- Specific surface area: 5.8 m^2/g;
- Pore volume: 0.023 cm^3/g;
- The adsorption curve is type II, indicating that it is mainly physical accumulation pores between particles.

Sample 2: Hydrothermal synthesis of nano H_2WO_4

- Specific surface area: 42.6 m^2/g;
- Pore size distribution center: 3.8 nm (typical mesopores);
- The presence of hysteresis loops indicates the presence of open mesoporous channels;
- Suitable for ion exchange, electrocatalysis and energy storage.

Sample 3: PVP template-assisted synthesis of mesoporous tungstate

- Specific surface area: 92.1 m^2/g;
- Total pore volume: 0.261 cm^3/g;
- Average pore size: 8.7 nm;
- This indicates that the sample has high porosity and good diffusion ability.

5. Structure-Performance Relationship Analysis

BET results are closely related to the properties of tungstic acid materials, and the following correlations are common:

Structural features	Corresponding application performance
High specific surface area	Enhance photocatalytic and electrochemical reaction rates
Mesopore distribution	Facilitates gas diffusion and electrolyte penetration
Narrow pore size distribution	Improve reaction selectivity and stability
High pore volume	Suitable for adsorbents, energy storage materials, and sustained-release platforms

For example:

- **Photocatalysis** : High specific surface area nano-tungstic acid can provide more surface active sites and improve redox efficiency;
- **Electronic slurry** : materials with uniform pore size are conducive to film formation and density control;

- **Gas-sensitive materials** : Mesoporous structures improve the gas molecule capture capability and response speed.

VI. CTIA GROUP BET Testing Standards and Data Application

In CTIA GROUP Tungsten Acid Powder Engineering System, BET analysis is used in the following aspects:

Application Scenario	Test Goal	Typical parameter range
Process Optimization	Determine the drying/ crystallization / pore-forming effects	The difference in specific surface area before and after the process is >10%
Finished product acceptance	Control batch stability	Batch difference < ± 5% (specific surface area)
Application Matching	Customized for photocatalysis and electrode materials	Surface area ≥40 m²/g, pore size 3–10 nm
Material screening	Nanoscale product quality grading	High surface area segment for high value-added markets

All tests are performed according to ISO 9277 standards, and the data are automatically archived in the CTIA GROUP "Functional Powder Quality Database".

VII. Summary

BET specific surface area and pore structure analysis is an important means to reveal the internal microstructure of tungsten acid materials, evaluate the reactivity of materials, and guide the selection of application paths. Combining pore size control strategy with specific surface area control technology can accurately optimize the performance of tungsten acid powder in cutting-edge materials such as high-performance energy storage, molecular recognition, and optoelectronic devices. It has important strategic significance for promoting the high-value utilization and engineering functionalization research of tungsten compounds.

4.7 Test methods for electrical and optical properties

Tungstic acid (H_2WO_4) and its derivatives are functional inorganic materials and are widely used in optoelectronics, sensors, electrochromic devices, energy materials and other fields. The key to its performance lies in **the electrical** and **optical properties of the material** , which are not only affected by the chemical composition, but also closely related to the crystal form, microstructure, impurity content and electronic state of the material.

This section will systematically introduce the commonly used test methods for the electrical and optical properties of tungstic acid, including test principles, equipment requirements, data interpretation, and their engineering significance in the functional evaluation and application development of tungstic acid.

1. Electrical performance test method

1. Conductivity test (resistance method/four-probe method)

Applicable to:

- Tungstic acid powder tableting;
- Tungstic acid film;
- Doped semiconductor tungstic acid.

Test method:

- **Four-probe method** :
  - Suitable for flake samples;
  - The voltage-current response is measured by using four needles to contact the sample surface simultaneously;
  - Reduce the influence of contact resistance on measurement error;
- **Two-probe/surface resistance meter** :
  - Commonly used to roughly measure the resistance of powder tablets.

Common parameter ranges:

Material Type	Conductivity range (S/m)	Features
Pure tungstic acid (non-conductive)	$10^{-8} – 10^{-12}$	Electrical insulation materials, mainly for dielectric purposes
Doped tungstic acid (Cu, Na, etc.)	$10^{-6} – 10^{-2}$	Semiconductor behavior, applicable to electrochromic devices

2. Dielectric properties test (LCR measurement)

Used to evaluate the polarization ability and energy loss of tungstic acid materials under alternating electric fields.

Measurement parameters:

- Dielectric constant (ε')
- Dielectric loss factor (tanδ)

Test conditions:

- Frequency range: 100 Hz – 1 MHz;
- Temperature control: room temperature to 150°C;
- Sample form: pressed tablet or film type, electrode plating (silver paste/gold film) is required.

3. Electrochromic test

Tungstic acid has electrochromic properties and can change color when voltage is applied. It is often used in smart glass, dimming devices, etc.

Test method:

- Prepare ITO conductive glass + tungstic acid film + electrolyte + counter electrode;
- Applied voltage (e.g. ±1 V);
- Record color change time, reaction rate, and repeated cycle stability;
- UV-Vis spectra can be used to record changes in light transmittance.

Key Metrics:

- Light variable transmittance difference (ΔT);
- Coloring efficiency (η, cm^2/C);
- Cycling stability (more than 50–1000 times).

4. Electrochemical testing (CV/EIS/GCD)

It is suitable for studying the electrochemical properties of tungstic acid in supercapacitors, batteries, and catalysis.

method	Test content	illustrate
CV (Cyclic Voltammetry)	Redox behavior, capacitance characteristics	The more standard the curve rectangle is, the closer it is to the ideal capacitor.
EIS (Electrochemical Impedance Spectroscopy)	Charge transfer resistance and capacitance fitting	Nyquist plot fitting equivalent circuit
GCD (Constant Current Charge and Discharge)	Specific capacitance, charge and discharge efficiency	Evaluating energy storage performance and stability

2. Optical performance test method

1. UV-Vis absorption spectrum

It is used to measure the absorption capacity of tungstic acid to light of different wavelengths and analyze its optical band gap and light response range.

Test subjects:

- Tungsten acid powder (solid diffuse reflectance mode);
- Tungstic acid thin film (transmission/absorption measurement);

Equipment configuration:

- UV-visible spectrophotometer;
- Integrating sphere accessory (for scattering samples);
- Test wavelength range: 200–800 nm.

Analysis content:

- Main absorption peak position (300–450 nm);
- Absorbance intensity (Abs);
- Absorption edge and optical band gap estimation (Tauc method):

(α h ν)n =A(hν − Eg)(\alpha h\ nu)^ n = A(h\nu - E_ g)(α h ν)n =A(hν − Eg)

- n=2n = 2n=2: direct band gap; n=½n = ½n=½: indirect band gap.

Common band gap values:

- H_2WO_4 : 2.6–2.9 eV (blue-violet light absorption);
- Doped tungstic acid: tunable to 1.8–2.4 eV.

2. Photoluminescence spectroscopy (PL)

The recombination behavior of photoinduced electron-hole pairs in tungstate materials is analyzed to reflect their band structure and defect states.

Test parameters:

- Excitation wavelength: 325 nm, 405 nm, etc.;

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- Measurement band: 350–700 nm;
- The main focus is on the luminescence peak position, intensity and fluorescence lifetime.

Typical phenomenon:

- The emission peak is in the 450–550 nm range, and the intensity varies with lattice defects or doping;
- Doping can inhibit non-radiative recombination and improve luminescence efficiency.

3. Photocatalytic performance test

Evaluate the ability of tungstic acid to degrade pollutants or dyes under UV/visible light irradiation.

Test method:

- Establish a reaction system (such as methyl orange/rhodamine B/MB, etc.);
- Set the light source (Xe lamp, LED, simulated sunlight);
- Take samples at regular intervals to measure changes in absorption;
- Calculate the degradation rate and apparent rate constant (k):

Ct/C0=e − ktC_t / C_0 = e^{- kt}Ct / C0 = e − kt

Applicable modified tungstic acid system:

- Nano tungstic acid, Cu doped tungstic acid, tungstic acid/graphene composite materials, etc.

3. Typical test cases and index requirements of CTIA GROUP

project	Test Method	Typical data	Engineering Application
Conductivity	Four-probe method	1.2×10^{-6} S/m (Cu doped)	Smart window control, electrode film
Electrochromic	ΔT = 36%, η = 48 cm^2/C	Fast coloring, cycle > 1000 times	Photochromic glass, electronically controlled coating
UV Absorption	λ = 412 nm, Eg ≈ 2.8 eV	High absorption rate	Photocatalytic materials
PL luminescence	Peak: 485 nm	Moderate	Optoelectronic devices
Photocatalysis	MB 90% degradation/40 min	Expanding green environmental protection field	Sewage treatment, air purification

4. Data interpretation and precautions

question	reason	suggestion
Conductivity cannot be measured	The sample is too insulating or the contact resistance is high	Use high-sensitivity LCR meter or pressure sintering
Bandgap valuation is high	Measuring absorption edge blur	Correction for reflection/scattering using an integrating sphere
CV curve distortion	The electrode contact is poor or the scan is too fast	Optimizing coating uniformity and electrolyte type

PL peak intensity is too strong/offset	Impurity defects or doping caused	Combined with XPS or Raman analysis

V. Summary

The electrical and optical properties of tungstic acid are the core manifestations of its application potential. Through the combination of various electrical and spectral techniques, its electronic structure, band gap properties, conductive behavior and functional response capabilities can be fully revealed, providing reliable data support for the construction of high-performance optoelectronic devices, electrochromic systems, photocatalytic reaction platforms, etc. Establishing a unified evaluation method system will help promote the standardized application and industrial promotion of tungstic acid materials in the field of functional materials.

Tungstic Acid Introduction
CTIA GROUP LTD

1. Tungstic Acid Overview

The tungstic acid (tungsten trioxide hydrate, $WO_3 \cdot H_2O$) produced by CTIA GROUP LTD is a high-purity yellow crystalline powder, manufactured using advanced precipitation and calcination processes. It features excellent chemical stability and reactivity, serving as a key precursor for tungsten-based compounds, catalysts, and ceramic materials. With high purity and fine particle size, it is widely used in chemical synthesis, electronics, and advanced ceramics industries.

2. Tungstic Acid Features

- Chemical Formula: $WO_3 \cdot H_2O$
- Molecular Weight: 249.85
- Appearance: Yellow crystalline powder
- Melting Point: Decomposes >100°C
- Density: 5.5 g/cm³
- Stability: Stable under dry conditions, decomposes in water to form tungstate ions, requires sealed storage
- Wide Applications: Used in catalyst preparation (selectivity >95%), tungsten oxide synthesis, ceramic pigments

3. Tungstic Acid Product Specifications

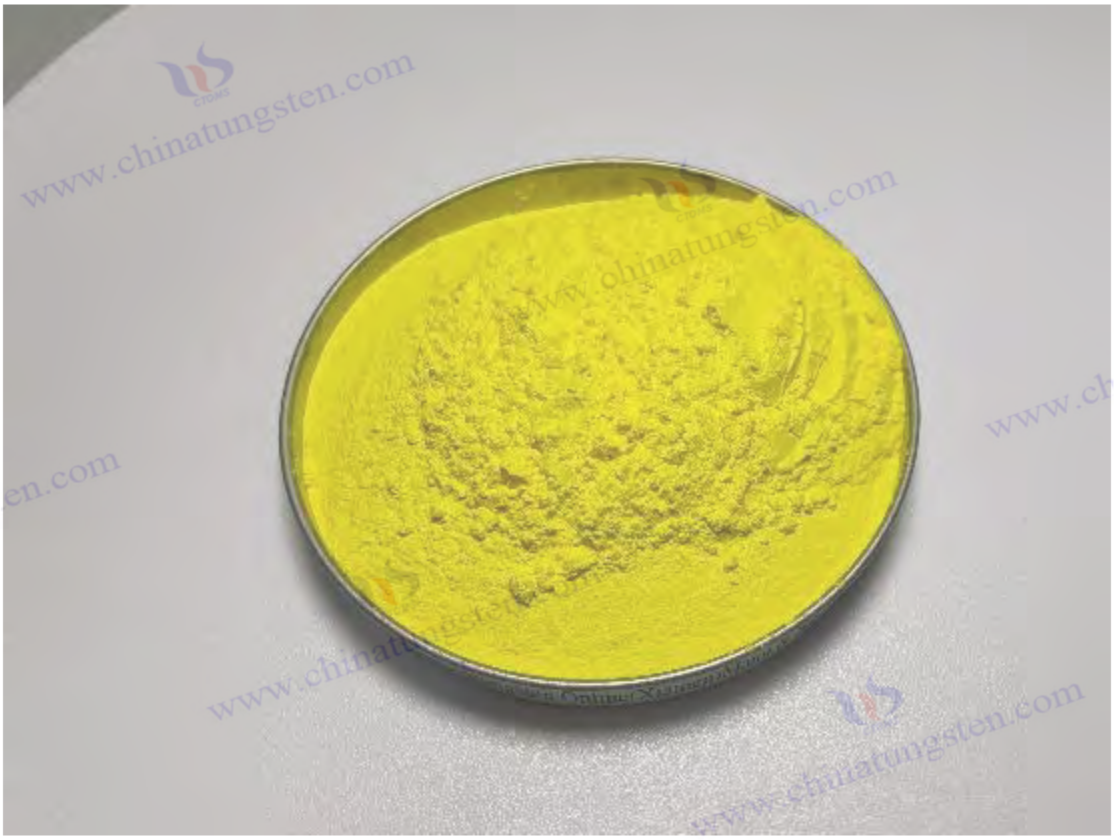
Grade	Purity (wt%)	Particle Size (μm)	Solubility	Impurities (ppm)
Reagent Grade	≥99.9	1–10	Slightly soluble	Fe≤10, Na≤5, Si≤10
Industrial Grade	≥99.5	1–10	Slightly soluble	SO_4^{2-} main, trace elements
Technical Grade	≥98.5	1–10	Slightly soluble	Minor oxide impurities allowed

4. Tungstic Acid Packaging and Quality Assurance

- Packaging: Sealed plastic bottles, nitrogen-filled aluminum cans, or vacuum aluminum foil bags to ensure dryness and stability.
- Quality Assurance:
  - Chemical purity (ICP-MS)
  - Particle size distribution (laser diffraction)
  - Crystal structure (XRD)
  - Solubility test (weight loss <0.1% in water)

5. Tungstic Acid Procurement Information

- Email: sales@chinatungsten.com
- Phone: +86 592 5129595
- Website: http://tungstic-acid.com



Chapter 5: Main derivatives and intermediates of tungstic acid

5.1 Metatungstates (such as sodium, ammonium, calcium, copper, etc.)

Paratungstates are tungstate compounds with metatungstate ions ($[W_{12}O_{42}]^{10-}$) as the core, and are one of the most important intermediates in tungsten chemistry. They are not only the key precursors for the preparation of tungsten oxides, tungstic acid derivatives, and metallic tungsten materials, but are also widely used in electronic ceramics, chemical catalysis, electroplating, and functional materials. Metatungstates with different cations, such as sodium metatungstate ($Na_{10}[W_{12}O_{42}]\cdot xH_2O$), ammonium metatungstate (APT, $(NH_4)_{10}[W_{12}O_{42}]\cdot xH_2O$), calcium metatungstate ($Ca_5[W_{12}O_{42}]\cdot xH_2O$), copper metatungstate ($Cu_3[W_{12}O_{42}]\cdot xH_2O$), etc. , show diverse engineering and scientific research values due to their different structures , solubility and thermal behavior .

1. Structure and Classification

The basic skeleton of metatungstate is a dodeca-tungsten oxygen tetradecene anion ($[W_{12}O_{42}]^{10-}$), which is a relatively stable polymer structure formed by twelve $\{WO_6\}$ octahedrons sharing edges or corners. This structure has a high degree of symmetry and can form stable crystals with a variety of cations by adjusting pH and ionic strength.

name	Chemical formula	Crystal structure	Cation Type
Sodium tungstate	$Na_{10}[W_{12}O_{42}]\cdot xH_2O$	Monoclinic/Orthogonal	Monovalent metal cations
Ammonium partial tungstate (APT)	$(NH_4)_{10}[W_{12}O_{42}]\cdot xH_2O$	Monoclinic/Hexagonal	Ammonium
Calcium tungstate	$Ca_5[W_{12}O_{42}]\cdot xH_2O$	Hexagonal/orthorhombic	Divalent alkaline earth metals
Copper Tungstate	$Cu_3[W_{12}O_{42}]\cdot xH_2O$	Quartet	Transition metal cations

2. Preparation method

1. Acidification crystallization method (APT preparation)

- sodium tungstate solution (Na_2WO_4) ;
- Acidifier: HCl, HNO_3 , H_2SO_4 to adjust pH to 3.0–3.5 ;
- Add NH_4Cl or NH_4NO_3 to provide ammonium ions ;
- React at controlled temperature (60–80°C) for 1–2 hours to allow slow crystallization;
- After washing and drying, APT crystals are obtained.

$$12Na_2WO_4 + 10NH_4Cl + 10HCl \rightarrow (NH_4)_{10}[W_{12}O_{42}]\downarrow + 22NaCl + 10H_2O$$

2. Ion exchange method (Ca^{2+} , Cu^{2+} doping)

- APT is used as a precursor and reacts with $CaCl_2$ or $Cu(NO_3)_2$ solution ;
- Control the pH between 4–6 to promote ion exchange;
- $Ca_5[W_{12}O_{42}]$ or $Cu_3[W_{12}O_{42}]$ type metatungstate can be obtained;
- The final product is washed and dried for storage to maintain the integrity of the crystal form.

3. Hydrothermal self-assembly method (polymorphic regulation)

- Suitable for preparing metatungstate with high crystallinity and special morphology;
- Hydrothermal reaction at 100–180°C;
- The particle size and morphology can be adjusted by additives such as PVP and PEG.

3. Performance characteristics

project	Description
Water Solubility	APT solubility is lower than Na_2WO_4 , which is conducive to precipitation separation
Thermal stability	It can be decomposed into tungsten trioxide at 600–800°C
Crystal morphology	APT is needle-shaped crystals, sodium is columnar crystals, and calcium is mostly flake-shaped
Tungsten content	theoretical tungsten content of APT is about 74.3%, which is higher than WO_3 (72.6%)
pH responsiveness	It can be stably precipitated under acidic conditions and easily hydrolyzed to WO_4^{2-} at pH＞7

WO_3 with uniform particle size through thermal decomposition , and then further reduced to obtain W powder. Therefore, its thermal behavior determines the quality of downstream tungsten powder.

4. Introduction of Typical Representatives

1. Ammonium tungstate (APT)

- The most common and with the largest output;
- Used as the starting material for metal tungsten powder, tungsten carbide, tungsten alloy, tungstate, etc.
- The process control standards are mature and highly adaptable.

2. Sodium tungstate

- As a tungsten intermediate, used in catalyst precursors;
- Long-term stability at neutral pH;
- It can be used for some low-temperature solid-state reaction synthetic materials.

3. Calcium tungstate

- Applied to lead-free ceramics and dielectric materials;
- Has good insulation and thermal stability;
- During sintering, a $CaWO_4$-like framework structure can be formed .

4. Copper tungstate

- Can be used for catalysis and antibacterial materials;
- Copper doping improves electrical conductivity and active oxygen formation ability;
- It is used in research to construct a photocatalytic/electrocatalytic composite system.

5. Engineering Application and Development Prospects

Application Areas	illustrate
Tungsten powder/ tungsten carbide preparation	APT thermal decomposition + hydrogen reduction is the most mainstream tungsten powder preparation route
Optical Ceramics	Calcium tungstate is used in luminescent substrates and laser crystals
Photocatalyst	Copper tungstate and other materials are used to construct heterojunctions and improve catalytic efficiency
Electrochemical Materials	Doped metatungstate systems for supercapacitor and battery electrodes
Green decolorizer	APT can be used with TiO_2 to construct a UV decolorization catalytic system

In the metatungstate business of CTIA GROUP , APT products have the advantages of serialization, standardization, and electronic- level control , with an annual output of over 1,000 tons, and have been successfully exported to markets such as Japan, South Korea, and Germany. In the future, we will combine green tungsten extraction technology to develop new crystal forms and multi-doping directions for metatungstate.

VI. Summary

Metatungstate is an important intermediate in the tungstic acid system with clear structure, superior performance and wide application. Its representative substance APT has become an indispensable raw material platform in the global tungsten industry chain. Through structural regulation, ion substitution, morphology engineering and other means, its application boundaries can be expanded, and metatungstate can be promoted to extend to new fields such as optical functions, energy, and catalysis, showing extremely high material and industrial strategic value.

5.2 Tungstate complexes (polytungstates, isopolyacids)

Tungstate complexes are polynuclear anion complexes formed by the polymerization of tungstate ions through oxygen bridges or structural rearrangement, and are generally referred to as "polyoxotungstates (PWTs)" or more generally "heteropolyacids (HPAs)". These compounds have a clear molecular structure, controllable component configuration and rich electronic properties, and are a very representative class of supramolecular systems in inorganic functional materials .

Tungstate complexes can not only be used as catalysts, electrode materials, photofunctional molecules, and proton conductors, but also show diverse application potential in the fields of medicine, sensing, antibacterial and molecular recognition. This section will deeply analyze its core structure type, synthesis path, physical and chemical properties, and its strategic significance in CTIA GROUP Research and product development.

1. Basic structural units and classification system

1. Polytungstate core structure

Basic building blocks: $\{WO_6\}$ octahedra
are aggregated by corner or edge sharing to form the following structures:

- **Isopolyoxotungstates :** self-assembled from tungstates, such as $[W_6O_{19}]^{2-}$, $[W_{12}O_{40}]^{8-}$;
- **Heteropolyacids (heteropolyoxotungstates) :** heteronuclear atoms (P, Si, Ge, etc.) are introduced into the center of the structure , such as:
  - Keggin structure: such as $[PW_{12}O_{40}]^{3-}$, $[SiW_{12}O_{40}]^{4-}$;
  - Dawson structure: such as $[P_2W_{18}O_{62}]^{6-}$;
  - Anderson structure: such as $[Cr(OH)_6W_6O_{18}]^{3-}$.

2. Classification system

type	Structural core	General formula	feature
Equivalent acid	Pure tungsten structure	$[W_nO_{3n+1}]^{m-}$	The structure is relatively symmetrical and easily soluble in water
Heteropoly Acid	Heteronuclear center + tungsten oxide cluster	$[XW_nO_m]^{p-}$	Strong acidity and diverse functions
Organic-inorganic hybrid	Polyacid + organic cation	$[PWT]@R^+$	Adjustable surface affinity
Doped polyacid	Introducing Mo, V, Ti, etc.	$[PW_{10}V_2O_{40}]^{5-}$	Expanding redox performance

2. Synthesis Pathway and Control Strategy

The synthesis of polytungstates is usually achieved through **acid precipitation self-assembly ,** the key of which lies in pH control, ionic environment regulation and the introduction of coordinating ions.

1. Heteropolyacid synthesis (Keggin type)

- Raw materials: Na_2WO_4 , H_3PO_4 (or sodium silicate) ;
- Acidification to pH 1–2;
- Heat to 60–80°C and stir continuously for 4–6 hours;
- Cooling, crystallization, recrystallization and purification;
- Keggin structure $H_3[PW_{12}O_{40}] \cdot xH_2O$ or its salts are obtained .

2. Doping/functionalization pathway

- Adding oxyacid salts such as V, Mo, and Ti to react synergistically;
- or introducing modifiers such as organic amines and organic phosphorus during the post-treatment stage;
- Hydrothermal treatment, ion exchange, interface self-assembly and other technologies assist in stabilizing the structure.

3. Synthesis of organic polyacid composites

- Complexing PWT with quaternary ammonium salts and small organic molecules;
- A water-oil two-phase controllable system can be constructed for use in coatings, electrochemical systems, etc.

3. Physical and chemical properties

nature	describe
Strong acidity	$H_3[PW_{12}O_{40}]$ and others have stronger proton releasing ability than H_2SO_4
High stability	Keggin type structure with thermal stability up to 400°C
Reversible redox	$W^{6+} \leftrightarrow W^{5+}$ transition, which can be used for charge storage and catalysis
Adjustable solubility	Adjustable dissolution behavior of salts such as K, Na, NH_4 , histamine, etc.
Structure can be characterized	Comprehensive analysis through IR, UV, NMR, XRD, ESI-MS and other means

4. Introduction of representative polytungstates

1. Keggin type heteropoly acid

- Molecular formula: $[PW_{12}O_{40}]^{3-}$, $[SiW_{12}O_{40}]^{4-}$;
- Strong acidity and stable structure;
- Used to catalyze esterification, oxidation, phenol hydroxylation and other reactions;
- It is the main platform molecule in the tungsten catalysis industry.

2. Dawson type polyacid

- Molecular formula: $[P_2W_{18}O_{62}]^{6-}$;
- Higher core count and larger space structure;
- It has unique properties in energy storage devices and self-healing coatings.

3. Doped polyacid

- Example: $[PW_{11}VO_{40}]^{4-}$, $[SiW_9Mo_3O_{40}]^{7-}$;

- Changes in redox potential;
- Expand the photoelectric activity window and improve catalytic selectivity.

4. Organic polyacid complex

- Most of them are quaternary ammonium salt and organophosphate modified types;
- Change the dispersibility and interfacial affinity of polyacids;
- Applied in biocatalysis, antibacterial membranes, and flexible devices.

5. Application Directions and Frontier Progress

Application Areas	Features	Typical Examples
Acid Catalyst	Esterification, hydrolysis, condensation	$H_3[PW_{12}O_{40}]$ as homogeneous catalyst
Photocatalysis	Visible light response, electron transfer	Composite catalytic degradation of dyes by $[SiW_{12}O_{40}]$ and TiO_2
Electrochromic Materials	Reversible W^{6+} / W^{5+} transformation	For smart glass and electrochromic films
Supercapacitors	Fast electron storage, ion diffusion	Dawson-type V-doped polyacid supported on carbon materials
Biological antibacterial	Destroy bacterial membranes and release oxides	Organic PWT for coating of medical contact materials
Molecular recognition and sensing	Metal coordination, proton response	Polyacids construct ion-selective electrodes and sensor interfaces

VI. CTIA GROUP Research Layout and Product Expansion

CTIA GROUP has established a pilot development platform for polyacid tungsten materials , mainly covering:

- Construction of heteropolyacid material library (Keggin /Dawson structures 50+);
- Development of organic polyacid composite membrane materials (membrane electrode/photocatalytic film);
- Commercialization of polyacid catalysts (liquid catalysts/immobilized carriers);
- Trial verification of doped PWT in energy/optical ceramics.

In the future, we will further expand the fields of vanadium- molybdenum co-doping, aggregation-induced emission (AIE) and bioactive polyacids to achieve a comprehensive breakthrough from functional structure to device platform.

VII. Summary

tungstate chemistry , tungstate complexes not only have extremely high academic value in basic research, but their acid catalysis, electronic behavior and molecular recognition properties also determine their broad prospects in catalysis, electrochemistry, energy and functional composite systems. Through structure-controlled synthesis, doping regulation and interface composite, tungstate complexes will become an important part of future functional material systems.

5.3 Organic tungstate esters and organic complexes

Organotungstic Esters and Organotungsten Complexes are important expansion forms in the field of tungstic acid chemistry and belong to organic-inorganic hybrid systems. These compounds form stable molecular structures through coordination, esterification, bonding, etc. of organic functional groups with tungstic acid or tungstate , and have good solubility, functionality and adjustable structural characteristics.

With the continuous development of green chemistry, homogeneous catalysis, and organometallic materials, organic tungstate esters and tungstic acid organic complexes have gradually demonstrated their unique advantages in catalysis, functional coatings, biomedicine, electrochemistry, and photoresponsive materials, and have become a key direction in CTIA GROUP's high value-added tungsten compound research and development system.

1. Definition and basic structure

1. Tungstic Esters

Organic tungstate esters refer to organic tungsten compounds formed by esterification of tungstic acid (H_2WO_4) or tungstate with organic alcohols (such as alcohol, phenol, allyl alcohol, etc.). Its basic structure generally contains W=O and W–O–R (R is an organic group) bonds.
Schematic formula:
R–O–W(=O) $_2$ – OH or R–O–[W $_{12}$ O $_{42}$] $^{n-}$

2. Organotungsten Complexes

Organic tungsten complexes refer more broadly to the coordination structure formed by tungsten and small organic molecules containing coordination groups (such as amines, carboxylic acids, phosphonic acids, organic amine salts, organic ligands), which may be mononuclear, binuclear or polynuclear.
Their structural stability and electronic behavior can be tuned by organic ligands, sometimes involving W–C or W–N direct bonding.

2. Synthesis Method

1. Esterification reaction method

- Tungstic acid or tungstate is used as the acid source;
- Reacts with alcohols (e.g. ethanol, phenol, nonanol);
- Under acidic or Lewis acid catalysis;
- low to medium temperature conditions (30–90°C);
- Commonly used solvents: alcohols, autolytic systems, dichloromethane.

Example reaction:
$H_2WO_4 + 2ROH \rightarrow (RO)_2WO_2 + H_2O$

2. Co-precipitation complexation method

- the tungsten source (such as APT, Na_2WO_4) with the organic ligand (EDTA, citric acid, thiourea, etc.) solution;
- Control pH in the range of 5–9;
- Hydrothermal or normal pressure reaction;
- It can form tungstate complexes stably encapsulated by organic ligands.

3. Solid phase additive method/solvothermal regulation method

- Often used to construct organic-inorganic hybrid materials;
- Use templates and surfactants to control product particle size and dispersibility;
- It is often used to construct organic tungstate/metal complex nanocomposites.

3. Typical Representatives and Their Structural Characteristics

type	Molecular formula/Structure description	Features
Diethyl Tungstate	$(EtO)_2WO_2$	Transparent, oily liquid, easily soluble in alcohol
Phenol Tungstate	$(PhO)_2WO_2$	Contains aromatic rings to improve thermal stability
Alcoholamine complex tungstate	$[WO_2(HL)_2]$ (L is alcoholamine)	Stable mononuclear complex structure, suitable for solution catalysis
W-PAA	Tungsten-polyacrylic acid complex	Good film-forming property, used for functional films
Schiff base tungsten complex	Contains W=N bond structure	Excellent photoresponse and magnetic properties

4. Performance characteristics

project	Performance Description
Solubility	Most of them are soluble in alcohols, ethers, and organic solvents
Thermal stability	Ester bond stability is moderate, suitable for environments ≤200°C
Electrical properties	With certain electron migration ability and adjustable band gap
Optical activity	There are π–π *and* n–π transitions, showing visible light absorption
Reactivity	Can participate in ester exchange, nucleophilic substitution , free radical reaction, etc.
Surface functionality	Can be used as self-assembled monolayers (SAMs) to construct molecular interface materials

5. Application fields

1. Homogeneous catalyst

- Esterification/amidation/oxidation/reduction catalysis;
- For example, phenol tungstate ester catalyzes the ring opening of alkylene oxide;
- It exhibits high selectivity and low side reactions.

2. Electrochromic coatings and smart films

- W-PAA or polypyrrole tungstate composite coating;
- It has reversible color changing ability and high optical regulation rate;

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- Used in flexible electronic devices, display window films, etc.

3. Medicine and biology

- Some tungstate esters exhibit antibacterial and antitumor activities;
- Used in research for protein modification and RNA recognition site construction.

4. Metal-Organic Framework (MOF) Building Blocks

- Tungstate ester is used as a node to connect with carboxylic acid/amino group;
- Can form stable metal organic porous materials;
- Used for gas adsorption, separation and photocatalysis.

5. Nanocomposite modifiers

- Organic tungsten complexes can be used as interface regulators;
- Applied to surface modification of electrode materials/graphene/oxides;
- Improve electrochemical performance and interface stability.

VI. Product development and research direction of CTIA GROUP

CTIA GROUP has currently developed a variety of tungsten acid organic complex systems and established the following technical platforms:

- **Product Series** :
  - Alcohol tungstate esters ($C_2 - C_{10}$) ;
  - Organic amine tungsten complex;
  - Organophosphate tungsten salts;
  - W-PVP, W-PEG composite dispersions;
- **Performance Platform** :
  - Electrochromic response system (10^2 cycles without attenuation);
  - Flexible conductive paste;
  - Intelligent anti-fog and light- responsive materials.

In the future, we will further expand the biodegradable tungstate esters, programmable optoelectronic functional materials and tungstate ester electrocatalytic systems, and expand the application boundaries in green energy and flexible functional devices.

VII. Summary

Organic tungstate esters and organic tungstate complexes represent the most diverse and flexible branches in the tungstate family. They not only provide functional properties such as solution processing, interface assembly, and electro-optical regulation for tungsten materials , but also show great potential in building interdisciplinary applications. Through molecular structure design and interface regulation, organic tungsten complexes will play a more important role in light, electricity, catalysis, sensing, biomedicine and other fields.

5.4 Tungstate-based functional materials and composites

Tungstic Acid-Based Functional Materials refers to a composite material system with specific electrical, optical, catalytic, energy storage, induction, structural strengthening and other functions, which is constructed with tungstic acid (H_2WO_4) or its derivative structure as the active phase, matrix or structural element. Such materials are usually assembled in coordination with organic, polymer, metal oxide, carbon-based materials or other metal salts, showing multi-dimensional properties far exceeding that of single tungstic acid.

With the development of functional composite material design theory and multi-scale construction technology, tungstic acid is gradually changing from the traditional precursor role to the core functional component, and is widely used in smart color-changing devices, electrochemical energy storage, flexible electronics, biocatalysis and environmental governance.

1. Material construction method and composite mechanism

The construction of tungstate-based functional materials can be divided into the following modes:

Construction Type	describe	Example
Inorganic-inorganic composite	Tungstic acid + metal oxide	WO_3 / TiO_2 photocatalytic materials
Inorganic-organic hybrid	Tungstic acid + polymer/organic ligand	W-PVP dispersion
Carbon-based composites	Tungstic acid + graphene/carbon nanotubes, etc.	W-GO composite electrode
Multifunctional collaborative system	It also has electrocatalysis, adsorption, etc.	W– Fe_3O_4 – MOF composite adsorption catalyst

Key building strategies include:

- In situ deposition methods (sol–gel, self-assembly);
- Co-precipitation/doping method;
- Hydrothermal/solvothermal synergistic reaction;
- Layer-by-layer assembly and surface modification;
- Template method (hard template/soft template configuration control);

2. Representative types of tungstate-based composite materials

1. Tungstic acid-metal oxide composite system

By introducing TiO_2 , ZnO , Fe_2O_3 , etc. , electron transfer channels or heterojunction interfaces can be formed, thereby improving photoelectric conversion or catalytic efficiency .

- **WO_3 / TiO_2** : used for UV/visible light catalysis;
- **WO_3 / Fe_2O_3** : Enhanced separation of photogenerated carriers;
- **WO_3 / CeO_2** : Improve anti-reduction ability and oxygen storage;
- **WO_3 / SnO_2** : Used in gas-sensitive devices to improve response rate.

2. Tungstic acid-carbon material composite system

The high conductivity, specific surface area and dispersibility of carbon materials are utilized to enhance electron transport and improve load capacity.

- **WO_3 /GO (graphene oxide)** : used for flexible supercapacitors and electrochromic devices;
- **WO_3 /CNT (carbon nanotube)** : improves structural stability and cycle life;
- **WO_3 /C (activated carbon, carbon cloth)** : suitable for energy storage and wastewater adsorption.

3. Tungstic acid-polymer hybrid system

Organic macromolecules or polymers can provide stable dispersion, flexible processing and film-forming functions for tungstic acid.

- **WO_3 / polypyrrole (PPy)** : used for flexible electrodes;
- **WO_3 /PVA/PEG** : forms a transparent electrochromic film;
- **WO_3 – protein complexes** : for biocatalysis and sensing applications.

4. Multi-component synergistic functional materials

Tungstic acid can be used as a catalytic, energy conversion or structural stabilization platform to construct multifunctional materials in collaboration with metals, organic frameworks, photosensitizers, etc.

- **WO_3 @MOF** : realize controllable pores + redox performance;
- **W–Ni–S composites** : for hydrogen evolution electrocatalysis;
- **Tungstate-porphyrin composites** : a dual-functional platform for photothermal therapy and photocatalysis.

3. Performance advantages and control methods

Tungstate-based functional materials have the following key advantages due to their structural diversity and chemical stability:

Performance Type	Advantages and features	Impact Factor
Electrochemical activity	Reversible W^{6+} /W^{5+} transition with significant capacitance response	Material morphology, conductive phase composite ratio
Optical performance	Bandgap adjustable, photochromic/electrochromic	Crystal form control, doping adjustment
Catalytic activity	The surface W=O/W–OH centers are abundant and easy to transfer electrons.	Specific surface area, hybrid ligand selection
Thermal stability	High temperature resistance and anti-aging	Crystal integrity, covalent bond structure
Film forming properties and flexibility	Synergizes with polymers to impart flexibility and extensibility	Molecular weight, hybrid interface affinity

The regulatory pathways include:

- Control synthesis temperature and pH to achieve precise morphology control;
- Introduce structure-directing agents to regulate specific surface area and pore distribution;
- Adjusting electron cloud density through organic ligands to enhance photocatalytic selectivity;
- Adjust the band gap and electron migration path by ion doping/surface modification.

4. Typical application fields and engineering practices

Application	Key Metrics	Material system
Electrochromic Window Film	ΔT＞30%, response time＜5s	WO_3 /PVA/PEG film
Supercapacitors	Specific capacitance>300 F/g, cycle life>10,000 times	WO_3 /GO / CNT composites
Photocatalytic degradation	Degradation efficiency>90%, visible light response	WO_3 / TiO_2 / graphene ternary composite
Gas Sensors	High sensitivity to NO_2 / H_2S and fast response	WO_3 / SnO_2 /Ag composite sensitive layer
Heavy metal adsorption	Adsorption capacity ＞ 250 mg/g, strong selectivity	WO_3 / biochar composite adsorbent
Flexible Electronics	Bend 500 times without performance degradation	Tungstic acid-PEDOT composite electrode

5. CTIA GROUP R&D Case

CTIA GROUP has completed the following research deployments in the field of tungstate- based functional composite materials:

- Establish a tungstate hybrid material process platform (annual trial production capacity of 50 tons);
- Formed three major series including "tungstate-based transparent film materials", "W-C flexible electrodes", and "W/MOF synergistic catalysts";
- Co-build the "Tungsten Acid Intelligent Coating Joint Laboratory" with universities to develop electrochromic and antibacterial self-healing functional systems;
- The developed "WO_3 / PPy /PVA composite film" has been successfully piloted in the smart dimming glass project.

VI. Summary

Tungsten acid-based functional materials and composites are becoming an important branch of the new material system due to their unique electronic structure, diverse adjustable properties and good composite compatibility. Through composite design, multi-scale regulation and performance synergy, tungsten acid not only serves as a reaction precursor, but also plays a core role as a strategic basic material in many cutting-edge technologies such as energy storage, sensing, catalysis, and optoelectronic devices. In the future, tungsten acid-based composite systems will further develop in the direction of multifunctional integration, green intelligence, and high integration.

5.5 Synthesis of high-valent tungsten oxide precursors with the participation of tungstic acid

stoichiometric tungsten oxides are a class of non-stoichiometric, defect-rich tungsten oxides with significant electrochromic, photothermal conversion, electrocatalysis, energy storage and sensing functional properties. Typical representatives include $W_{18}O_{49}$, $W_{20}O_{58}$, $W_{25}O_{73}$, etc., which show richer electronic behavior, higher oxygen vacancy density and better electrochemical activity than WO_3.

Tungsten acid (H_2WO_4) is an important raw material for constructing these high -valent tungsten oxide precursors due to its high degree of hydration, strong reactivity, and easy-to-control morphology and structure. By rationally regulating the heat treatment, reducing atmosphere, precursor ligands, and reaction conditions of tungsten acid, precise control of the product phase composition, morphology, and redox characteristics can be achieved.

一、 Basic structure and characteristics of high-valent tungsten oxide

1. Chemical formula and structural characteristics

name	general formula	Oxygen/ Tungsten Ratio	Feature Structure
$W_{18}O_{49}$	$WO_{2.72}$	2.72	Oxygen-deficient tailored structure, O vacancies are highly ordered
$W_{20}O_{58}$	$WO_{2.9}$	2.90	Intercalation of vacancy chains between lattices, excellent conductivity
$W_{25}O_{73}$	$WO_{2.92}$	2.92	Similar to WO_3, with mixed valence W^{5+} / W^{6+}
WxOy nanoribbons /wires	Non-stoichiometric	2.6–2.95	Usually single crystals or ordered defect fragments

These structures are W - rich with high oxygen vacancy concentrations, and their electrical conductivity can be enhanced by 1–2 orders of magnitude while retaining a wide optical response window.

2. Key Performance Indicators

performance	Numerical range	contrast
Conductivity	10^{-3}– 10^{-1} S/cm	Higher than WO_3 (10^{-6} – 10^{-7} S/cm)
Band Gap	2.1–2.5 eV	Significantly enhanced visible light response
Oxygen vacancy density	＞10^{21} cm^{-3}	Improve electrocatalysis and ion transport rates
Light absorption	λ = 400–800 nm	Surface plasmon resonance occurs

2. Advantages of tungstic acid as a precursor

Tungstic acid has the following key advantages in the synthesis of high-valent tungsten oxides:

characteristic	Performance
Strong reactivity	The structure contains water and dense hydroxyl groups, which is easy to thermally decompose and phase transition

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Controllable crystal shape	Different crystal forms can be obtained by pH and hydrothermal regulation
Ion exchange capacity	Forming intermediate structures with carbon, metal, and ligand
High dispersibility	Helps control oxide particle size and defect formation
Dopability	Cu, Ni, Mo, etc. can be introduced in situ to enhance the electrical activity

3. Typical synthesis pathways and key control points

1. Atmosphere controlled pyrolysis

The tungstic acid is heated in a controlled atmosphere to achieve the conversion from H_2WO_4 → Conversion of WxOy .

step	condition	result
Drying pretreatment	80–100°C	free water to form $WO_3 \cdot xH_2O$
Heat treatment stage	400–600°C (N_2 /H_2 / Ar)	Achieving WO_3 → $W_{18}O_{49}$ etc.
Atmosphere Control	Slightly reducing atmosphere (5–10% H_2)	Preserve some W^{5+} state
Cooling method	Rapid cooling	Inhibition of W^{6+} re -formation

Commonly used equipment includes tubular furnace, vacuum furnace, plasma atmosphere furnace, etc.

2. Hydrothermal reduction method

- Introducing reducing agents (e.g., citric acid, glucose, alcohol) into hydrothermal reactions;
- React under mild conditions (180–220°C) for 12–24 hours;
- $W_{18}O_{49}$ nanowires, sheets, rods, etc. can be obtained;
- The ratio of oxygen vacancies can be adjusted by controlling the precursor concentration and reaction pH.

3. Organic ligand-assisted method

- Formation of complexing intermediates through polyethylene glycol (PEG), polyvinyl pyrrolidone (PVP), etc.;
- Improve particle dispersibility and control crystal growth;
- Subsequent heat treatment or inert atmosphere cracking obtains the target oxide.

4. Structural Control and Characterization Methods

Control parameters	Influence	Characterization methods
Heat treatment temperature	Determining the oxygen/ tungsten ratio and defect density	TG/DSC, XRD
Atmosphere Type	Regulating the W^{5+} / W^{6+} ratio	XPS、EPR
Time Control	Determines grain size and morphology	SEM/TEM
Doping elements	Imparting electrocatalytic or photoresponsive properties	ICP-MS, XRD, FTIR

Typical structural characteristics include:

- **XRD** : shows the splitting of $W_{18}O_{49}$ characteristic peaks ;
- **XPS** : W^{5+} accounts for 30–60% in the W4f region;
- **TEM** : visible crystal boundaries and defect stripes;
- **UV-Vis** : The absorption peak shifts to the blue region of the visible light region and the band gap decreases.

5. Application Examples and Performance Advantages

1. Electrochromic Device (ECD)

- Enhanced ion intercalation behavior using high W^{5+} concentration ;
- $W_{18}O_{49}$ responds 30% faster than WO_3 and has a 2 -fold increase in cycle life.

2. Photocatalytic and photothermal materials

- Oxygen vacancies promote electron-hole separation;
- $W_{18}O_{49}$ nanobelts can achieve efficient degradation of organic pollutants under visible light ;
- Photothermal conversion efficiency > 60%, used for photothermal therapy or solar steam system.

3. Electrochemical energy storage materials

- The specific capacitance of $W_{18}O_{49}$ electrode can reach 450 F/g ;
- is more than 30% better than WO_3 ;
- After being combined with carbon materials, the cycle performance is improved to more than 8,000 times.

4. Gas sensors and photodetectors

- Oxygen vacancies enhance the adsorption and charge transfer of gas molecules;
- Can be used for low concentration detection of NO_2, H_2S, ethanol , etc.
- It exhibits excellent photoresponse characteristics in the near-infrared region.

6. Research and pilot production direction of CTIA GROUP

CTIA GROUP has carried out the following work in the development of high-priced tungsten oxides:

Platform construction	content
Reaction Path	Establish more than 9 controllable synthesis routes starting from tungstic acid
Finished product morphology library	Establish 8 morphology control systems including nanorods, sheets, and wires
Material system	Launched 3 types of $W_{18}O_{49}$ - based composite electrode slurries and photothermal materials
Application pilot	Cooperate with terminal manufacturers to carry out product verification of electrochromic and energy storage electrodes

the engineering level of high-valent tungsten oxide materials by focusing on oxygen vacancy control technology, in-situ doping mechanism and flexible device integration path.

VII. Summary

Tungsten acid is not only a classic precursor of tungsten powder and tungsten oxide materials, but also a key platform material in the precise synthesis of high-valent tungsten oxides. By controlling its structure, reaction conditions and transformation mechanism, tungsten acid can achieve efficient evolution to defect -rich tungsten oxides such as $W_{18}O_{49}$, giving the material higher electronic activity and multi-dimensional functions. In the future, this direction will play a more critical strategic role in the fields of smart energy, environmental protection, advanced manufacturing, etc.

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Tungstic Acid Introduction

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1. Tungstic Acid Overview

The tungstic acid (tungsten trioxide hydrate, $WO_3 \cdot H_2O$) produced by CTIA GROUP LTD is a high-purity yellow crystalline powder, manufactured using advanced precipitation and calcination processes. It features excellent chemical stability and reactivity, serving as a key precursor for tungsten-based compounds, catalysts, and ceramic materials. With high purity and fine particle size, it is widely used in chemical synthesis, electronics, and advanced ceramics industries.

2. Tungstic Acid Features

- Chemical Formula: $WO_3 \cdot H_2O$
- Molecular Weight: 249.85
- Appearance: Yellow crystalline powder
- Melting Point: Decomposes >100°C
- Density: 5.5 g/cm³
- Stability: Stable under dry conditions, decomposes in water to form tungstate ions, requires sealed storage
- Wide Applications: Used in catalyst preparation (selectivity >95%), tungsten oxide synthesis, ceramic pigments

3. Tungstic Acid Product Specifications

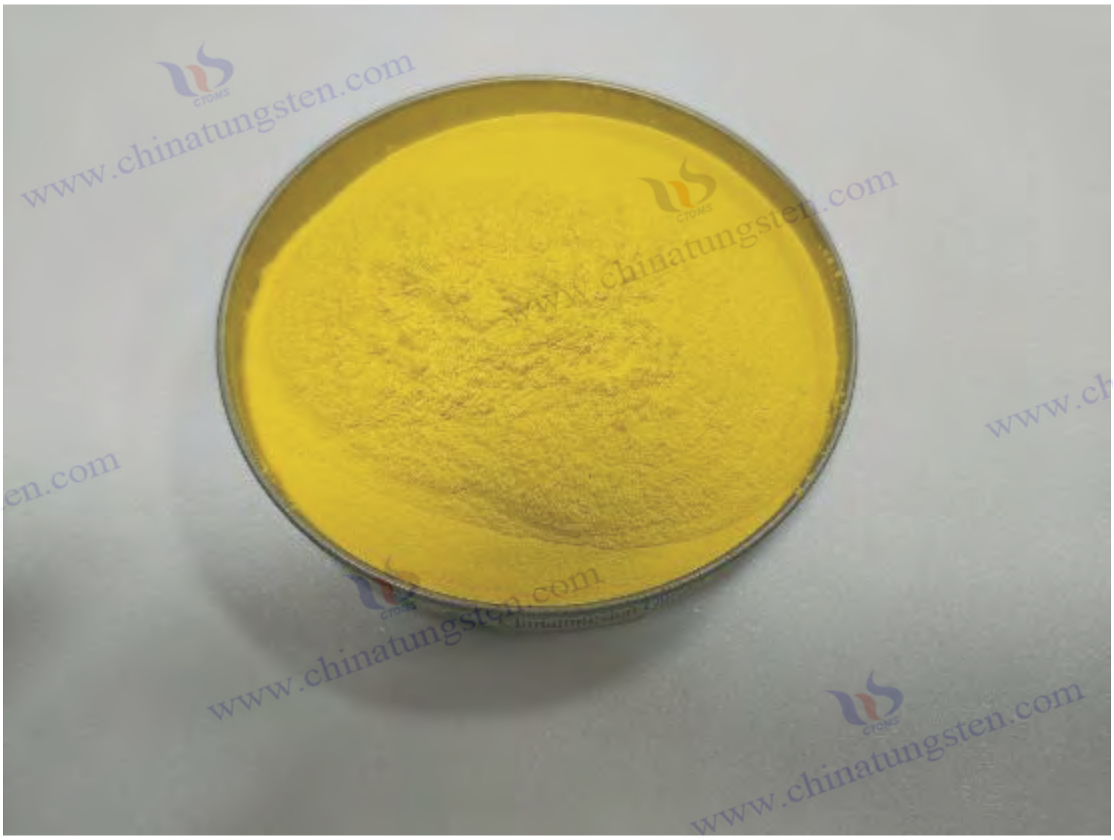
Grade	Purity (wt%)	Particle Size (μm)	Solubility	Impurities (ppm)
Reagent Grade	≥99.9	1–10	Slightly soluble	Fe≤10, Na≤5, Si≤10
Industrial Grade	≥99.5	1–10	Slightly soluble	SO_4^{2-} main, trace elements
Technical Grade	≥98.5	1–10	Slightly soluble	Minor oxide impurities allowed

4. Tungstic Acid Packaging and Quality Assurance

- Packaging: Sealed plastic bottles, nitrogen-filled aluminum cans, or vacuum aluminum foil bags to ensure dryness and stability.
- Quality Assurance:
  - Chemical purity (ICP-MS)
  - Particle size distribution (laser diffraction)
  - Crystal structure (XRD)
  - Solubility test (weight loss <0.1% in water)

5. Tungstic Acid Procurement Information

- Email: sales@chinatungsten.com
- Phone: +86 592 5129595
- Website: http://tungstic-acid.com



Chapter 6: Application of Tungstic Acid in Inorganic Industry

6.1 The role of tungstic acid in the tungsten compound industry chain

Tungstic acid (H_2WO_4) is a key intermediate in the tungsten industry chain, connecting primary tungsten resources (APT, tungsten concentrate) and high-performance tungsten materials (such as tungsten oxide, tungsten powder, tungsten alloy, tungstate, tungstate ester, organic tungsten complex). As a high-purity, well-defined, and reactive inorganic compound, tungstic acid is not only widely used in industrial preparation, but also plays an irreplaceable supporting role in the development of new materials and the synthesis of functionalized tungsten derivatives.

This section will systematically explain the raw material sources, preparation processes, derivative directions of tungsten acid in the entire life cycle of tungsten compounds and its functional status at key upstream and downstream nodes in the industrial chain, demonstrating its core role as a "bridge material for tungsten fine chemicals".

1. Brief structure and core nodes of tungsten industry chain

The tungsten industry chain can usually be divided into the following four levels:

Tiers	Main Products	Process route	Typical Representatives
Upstream	Tungsten concentrate , wolframite, scheelite	Leaching, roasting, decomposition	WO_3 、 APT
Midstream	Tungstic acid, intermediate oxide	Acid hydrolysis, crystallization, thermal decomposition	H_2WO_4 、 $WO_{2.9}$
Downstream	Functional Tungsten Materials	Reduction, doping, compounding	W powder, tungstate, coating
terminal	Tungsten products	Molding, sintering, application	Cemented carbide, electrode materials, electronic packaging

Tungstic acid is located at the midstream hub position. It can be prepared from APT and can also be used as a precursor for WO_3 , metallic tungsten, and chemical tungsten products . It is an indispensable material form connecting the upstream and downstream.

2. Preparation Path and Raw Material Adaptability of Tungstic Acid

1. Source of raw materials

Tungstic acid is mainly obtained by acidolysis of APT (ammonium tungstate) or neutralization of sodium tungstate. Its core reactions include:

APT acid hydrolysis method :

$(NH_4)_{10}[W_{12}O_{42}] + 10HCl \rightarrow 12H_2WO_4\downarrow + 10NH_4Cl$

Na_2WO_4 reacts with **strong acid :**

$Na_2WO_4 + 2HCl \rightarrow H_2WO_4\downarrow + 2NaCl$

2. Process route characteristics

- It can realize continuous control and high-purity preparation;
- The crystal form and particle size can be precisely controlled by adjusting pH, reaction temperature and aging time;
- Easy to carry out doping/modification/precursor design to meet diverse derivative needs.

Currently, CTIA GROUP has established a tungstic acid production line with an annual output of more than 1,500 tons, which can produce industrial-grade, electronic-grade, ultrafine, nano-tungstic acid and other series of products to meet the process standards of different downstream fields.

2. Downstream derivative direction and industrial chain extension of tungstic acid

Tungstic acid is the "original matrix" of most tungsten compound products, and its derivative directions include:

Derived Class	Typical products	Application Areas

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Tungsten Oxide	WO_3 , $WO_{2.9}$, $W_{18}O_{49}$	Energy storage devices, electrochromic devices, gas sensors
Tungsten Metal	W powder, W particles, nano tungsten	High-density metal, military industry, aerospace
Tungstate	Na_2WO_4 , $CaWO_4$, $CuWO_4$	Luminescent materials, functional ceramics
Organic tungsten compounds	$W(CO)_6$, tungstate ester	Homogeneous catalysis, organic synthesis
Tungstate complex	Polyacid, hybrid materials	Catalysts, electrode materials

The structural active centers of tungstic acid (W=O, W–OH) and its controllable crystal water behavior make it both reactive and stable in these conversion reactions, making it a highly cost-effective comprehensive tungsten source.

4. The "core function" of tungstic acid in the industrial chain

1. Provide a diverse precursor base to downstream

Tungsten acid can be converted into WO_3 (tungsten oxide), $WO_{2.9}$ (blue tungsten oxide), and W powder (metallic tungsten) through different heat treatment atmospheres and temperatures, achieving the goal of "adjustable structure, selectable crystal form, and controllable morphology".

2. Ideal starting point for the construction of catalysts and high-performance oxides

In the synthesis of high-performance inorganic systems such as metatungstates, heteropolyacids, and photocatalysts, tungstic acid is widely used to construct complex tungsten-based skeleton structures due to its high reactivity and strong coordination ability with organic ligands or metal ions.

3. "Process buffer zone" connecting upstream and downstream

Tungstic acid can balance the problems of APT purity and WO_3 redox shift. It is used as a regulating intermediate in actual production, for example, to prepare WO_3 slurries of different particle sizes and to homogenize the reduction reaction rate of tungsten powder.

4. Multifunctional material platform supporting role

Tungstic acid itself is also used directly to build composite materials, such as:

- Tungstic acid–PVA hybrid film: electrochromic;
- Tungstic acid–CNT composite: flexible electrode;
- Tungstic acid – TiO_2 heterojunction : photocatalysis.

V. Synergistic Status and Advantages in Industrial Integration

1. Strong modular integration capabilities

Tungsten acid, in solid or slurry form, is highly adaptable and can be directly incorporated into existing tungsten product modules, such as:

- Direct spraying as slurry;
- Blended with organic resin to form electrode film;
- Participate in the co-firing reaction in ceramic preparation.

2. Obvious advantages of green environmental protection

Compared with APT or high-temperature WO_3 treatment , tungstic acid has low energy consumption and low corrosiveness during the preparation and conversion process, and produces fewer by-products (such as NH_4^+) , making it more suitable for the development of a green tungsten industry chain.

3. Strategic supply chain security nodes

high-purity, ultrafine tungsten powder , tungstic acid has become an important link in domestic substitution and raw material security for high-end tungsten products. Its controllability and high adaptability can improve the risk resistance of the industrial chain .

VI. Typical Practice of CTIA GROUP Tungsten Acid Industry Chain

Link	Implementation content	Results
Raw material handling	APT → Tungstic Acid Conversion Process Optimization	High purity tungstic acid (W content＞74.2%)
Crystal form control	Different aging processes control crystal morphology	Controllable production of flake, columnar and spherical tungstic acid
Downstream connection	Tungstate slurry → spray WO_3 film → photochromic application	Realize integrated film production line
Export business	Tungstic acid is exported to Japan, the United States, Germany and other countries	Used in the field of luminescent materials and electronic ceramics

VII. Summary

a key material in the tungsten compound industry chain, tungstic acid not only plays a basic supporting role in the manufacture of traditional tungsten powder and tungsten alloys, but also expands its application boundaries in emerging tungsten-based functional materials , catalysts, electronic coatings, etc., with its excellent reactivity, structural adjustability and process adaptability. In the process of building a green, high-performance and intelligent tungsten material system in the future , tungstic acid will continue to play a core role as a strategic platform material.

6.2 Application of Tungstic Acid in Luminescent Materials

Tungstic acid (H_2WO_4) and its derivatives have a wide range of applications in the field of luminescent materials. With their unique electronic structure, wide bandgap characteristics, good crystallinity and dopability , tungstic acid and its conversion products are not only important components of phosphor matrix materials, but also have a place in cutting-edge optical devices such as electroluminescence, photoluminescence, X-ray fluorescence conversion materials and photonic crystals.

Starting from the structural characteristics of the materials, this section will systematically explore the mechanism of action, typical material systems, preparation methods and practical applications of tungstic acid and its complexes in luminescent materials, focusing on the performance of tungstic acid in rare earth doping luminescence, metal ion activation, ultraviolet response and nano-optics.

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1. The basis and mechanism of tungstic acid luminescence performance

1. Optical band gap and excitation characteristics

Tungsten oxide materials (such as H_2WO_4 , WO_3 , and WO_4^{2-} salts) have a wide optical band gap (2.5–3.2 eV) and do not have strong luminescence properties themselves, but can be stimulated to emit luminescence responses of different wavelengths through doping , defect introduction, and structural regulation.

Its luminescence properties are mainly derived from the following mechanisms:

type	describe
Charge transfer transition (CT)	$^{-}$ → W^{6+} in WO_6 octahedron forms band gap luminescence
Exciton recombination luminescence	Surface states, oxygen vacancies, etc. lead to exciton binding luminescence
Impurity level excitation	New energy level luminescence center introduced by rare earth or transition metal doping

2. Relationship between structure and luminescence center

Tungstic acid is composed of WO_6 structural units, forming various crystal forms (orthorhombic, monoclinic, triclinic, etc.). The symmetry and distortion of the crystal structure directly affect its band structure and luminescence behavior. In addition, ion doping can introduce localized energy levels into its crystal, thereby significantly enhancing or adjusting its luminescence performance.

2. Types of tungstate-derived luminescent materials

1. Rare earth doped tungstate luminescent materials

Using tungstate or its salts as the matrix, rare earth ions (such as Eu^{3+} , Tb^{3+} , Dy^{3+} , etc.) are introduced to construct the luminescence center.

- **Na_2WO_4 :Eu^{3+}** : red light emission, suitable for LED;
- **$CaWO_4$:Tb^{3+}** : Green fluorescent material, used in security marking and detection;
- **$SrWO_4$:Dy^{3+}** : blue-white light emission, suitable for white light illumination;
- **$La_2(WO_4)_3$: Sm^{3+}** : used in electroluminescent devices.

Features and advantages:

- High energy transfer efficiency (WO_4^{2-} → RE^{3+});
- Strong stability, suitable for long-term lighting and device packaging;
- It can realize multi-band regulation and three-primary color luminescence design.

2. Tungstate-based luminescent glass and ceramics

Tungstates (such as $PbWO_4$, $CaWO_4$) can be used as high refractive index and high density luminescent glass matrix materials.

- **Lead tungstate crystal ($PbWO_4$)** :
  - Has excellent X-ray conversion efficiency;
  - Used in high energy physics detectors and security inspection systems;

- The emission peak is usually between 420–500 nm;

- **$WO_3 – P_2O_5 – B_2O_3$ system glass** :
  - Doping with Eu^{3+} and Er^{3+} can form red/green luminescent glass;
  - It can be used in lasers and near-infrared amplifiers.

3. Tungstate composite quantum dots and nanoluminescent materials

tungstic acid with CdS , ZnO , carbon quantum dots and other materials can improve luminous efficiency and stability.

- **WO_3 / CdS composite quantum dots :** have a wider luminescence band;
- **WO_3 /Graphene quantum dots** : enhanced blue light emission, suitable for biological fluorescence labeling;
- **Tungstate-coated core-shell structure** : improved fluorescence stability and controllable emission behavior.

3. Preparation process of tungstate-based luminescent materials

1. Solid phase reaction method

- Suitable for preparing large quantities of crystalline tungstate;
- Usually requires high temperature calcination (600–1000°C);
- It is suitable for preparing $CaWO_4:RE^{3+}$ and other densely structured luminescent bodies.

2. Hydrothermal method and co-precipitation method

- Synthesize low-temperature, high-crystallinity, and controllable-size nanoscale luminescent materials;
- By controlling parameters such as pH, temperature, and time, monodisperse microspheres or flake structures can be achieved.

3. Sol-Gel and Glass Melt Methods

- Applicable to luminous glass and film materials;
- Rare earth ions or quantum dots can be doped to achieve multi-mode luminescence function.

4. Atomization spray pyrolysis

- Used for large-scale preparation of spherical phosphors;
- The particles have uniform morphology and are suitable for lighting coatings and LED chip packaging.

4. Performance Control and Application Examples

Control parameters	Effect on luminescence performance	Application Examples
Doping concentration	Changing the luminous intensity and luminous lifetime	Eu^{3+}The optimum concentration is about 3–5 mol%

Crystal form	Different crystal forms affect the band structure	Orthogonal phase tungstate has higher luminescence efficiency
Defective state regulation	Oxygen vacancies induce new luminescence centers	$W_{18}O_{49}$ emits blue light
Particle size	Nanoscale increases surface area and excitation efficiency	Nano-$CaWO_4$ fluorescent label

Typical application cases:

- **LED phosphor** : WO_4^{2-}:Eu^{3+} red light powder can be used for white light LED;
- **X-ray conversion materials** : $PbWO_4$ crystals are used in high-energy physics experiments;
- **Fluorescent probe** : WO_3 nanoparticles can be used as cell fluorescent probes after modification;
- **Reflective and anti-counterfeiting materials** : Tungstate luminophores are used in anti-counterfeiting inks for certificates and currency.

5. CTIA GROUP Luminescent Materials R&D Practice

CTIA GROUP has built the following R&D system around tungsten acid-based luminescent materials:

Modules	Specific content
Raw material guarantee	Provide high-purity electronic grade H_2WO_4 and Na_2WO_4 ;
Compound R&D	Establish a database of RE^{3+} - doped tungstate materials;
Process system	Realize the large-scale preparation of luminescent tungstate by low-temperature hydrothermal method;
Application landing	Cooperate with domestic LED packaging factories to develop a dimmable three-color fluorescent system;
Patented Technology	Tungstate-based red phosphor/blue film already has 5 core invention patents.

VI. Summary

The application of tungstic acid and its derivatives in luminescent materials not only provides matrix materials with superior performance and stable structure for optoelectronic technologies such as LED, laser, and fluorescence detection, but also shows unique value in emerging fields such as nanophotonics, bioimaging, and X-ray detection. Through crystal engineering, doping regulation, and multi-scale composite design, tungstic acid-based luminescent materials are becoming an important supporting platform in high-performance inorganic photonic material systems.

6.3 Tungstic Acid for High-Performance Ceramic Raw Materials

With the development of advanced manufacturing, extreme service environment and functional material technology, higher performance requirements are put forward for ceramic materials.

Tungstic acid (H_2WO_4) and its derivatives are widely used in high-performance ceramic systems due to their excellent thermal stability, high melting point, high density and good reactivity. They can be used as the main raw materials of functional ceramics and as structural modifiers or doping aids for ceramic composite materials.

This section will systematically introduce the action mechanism, application direction, composition system and preparation technology of tungstic acid as a ceramic raw material. Combined with the R&D practice of CTIA GROUP , it will deeply analyze its material contribution and industrial value in core fields such as electronic ceramics, structural ceramics, laser ceramics, etc.

1. The intrinsic advantages of tungstic acid in ceramic raw materials

property	Symptoms	Contribution to ceramics
High melting point	conversion to WO_3, the melting point is 1473°C	Imparting high temperature stability to ceramics
Strong reaction activity	Easily react with alkaline earth and rare earth elements to form salts	Facilitates solid phase reaction synthesis
High density	Theoretical density: about 7.1 g/cm³	Suitable for making high-density structural ceramics
Adjustable crystal structure	Polymorphic, controllable morphology	Adapt to different lattice matching requirements
Ion doping	Elements such as Cu, Y, and La can be introduced	Realize functional regulation and modification
Controllable particle size	Supports nanometer to micrometer scale distribution	Optimizing ceramic sintering and density

2. Application Directions and Typical Ceramic Material Systems

1. Tungstic acid is used in functional ceramics

- **Dielectric Ceramics** :
  - Typical systems: $CaWO_4$, $BaWO_4$;
  - Used in microwave dielectrics, capacitor ceramics, and dielectric resonators;
  - Tungstic acid is its key precursor, which forms composite ceramics after solid-phase reaction with $CaCO_3$, $BaCO_3$, etc.
- **Piezoelectric ceramics** :
  - Tungsten acid is introduced to regulate the lattice rigidity and polarization behavior of ceramics;
  - For example , $K_{0.5}Na_{0.5}NbO_3$ - WO_3 is a lead - free piezoelectric material ;
  - Tungstic acid improves the dielectric constant and electrostrictive properties.

2. Tungstic acid is used in structural ceramics

- **Tungstic acid reinforced alumina ceramics** :
  - Improve thermal conductivity and fracture toughness;

   - to form $Al_2O_3 - WO_3$ synergistic phase boundary ;
   - Suitable for wear and heat resistant devices.
- **$ZrO_2 - WO_3$ composite ceramics** :
   - Tungstic acid participates in forming a uniform second phase distribution;
   - Improve thermal shock resistance and corrosion resistance.

3. Laser ceramics and scintillation ceramics

- Tungstates such as $PbWO_4$ and $CaWO_4$ are the basic materials for X-ray responsive ceramics;
- Transparent W-series ceramics have excellent photoelectric conversion efficiency;
- Rare earth ions can be doped to construct laser-excited ceramic matrices.

4. Nano-ceramic composite materials

- Tungstic acid is introduced as nanoparticles to inhibit grain growth;
- Accelerate the sintering rate, improve density and mechanical properties;
- Commonly used in Si_3N_4, BN, TiO_2 composite structure ceramic systems.

3. Typical preparation methods and technical points

method	Process Description	Advantages
Solid phase reaction method	Tungstic acid + carbonate or oxide mixture, high temperature roasting	Mature technology, low cost
Sol-Gel Method	hydrolysis of tungstic acid and metal alkoxide	Controllable nanostructure and uniform composition
Coprecipitation	Tungstic acid participates in metal ion co-precipitation and low temperature pre-sintering	Good dispersibility, suitable for batch preparation
Aerogel/Spray Drying	Obtain spherical tungstate precursor to improve formability	For high performance injection molded ceramics

Sintering points:

- Sintering temperature: 1000–1350°C (depending on the material system);
- Atmosphere control: air, nitrogen, slightly reducing atmosphere;
- Ceramic density: >95% theoretical density is the engineering requirement;
- Sintering aids: Li_2O , ZnO , etc. can be introduced to assist sintering.

4. Performance Improvement and Engineering Advantages

After tungstic acid is introduced into ceramic materials, the following properties can be effectively improved:

project	Improvement direction	Effect description
Thermal stability	Improve melting point and thermal conductivity	Continuous use temperature ＞1000°C

Electrical properties	Controlling dielectric constant and Q value	Q×f value increased by 20–60%
Mechanical strength	Improve fracture toughness	Enhanced structural ceramics KIC value increased to 8–10 $MPa \cdot m^{1/2}$
Optical performance	Transparency and laser response enhancement	Ceramic substrate materials for laser
Corrosion resistance	Surface tungsten oxygen network inhibits acid and alkali corrosion	Applied to chemical reactor lining ceramics

5. Typical application scenarios and actual product cases

Application Areas	Typical Materials	Performance Indicators
Microwave dielectric ceramics	$BaWO_4$, $CaWO_4$	$\varepsilon = 6–9$, $Q \times f > 10000$
Medical/Nuclear Detection Ceramics	$PbWO_4$	Light output > 60% NaI:Tl , strong radiation resistance
Wear-resistant ceramic lining	$ZrO_2 – WO_3$	Hardness > 12 GPa , low friction coefficient
Laser Amplifying Ceramics	$La_2(WO_4)_3:Nd^{3+}$	Stable laser output power and high thermal conductivity
Infrared window ceramics	$MgO–WO_3$ based transparent ceramics	Infrared transmittance > 75%, suitable for aerospace optical devices

VI. CTIA GROUP Technology and Industrialization Progress

CTIA GROUP has formed a stable supply chain and a variety of customized models in the development of tungstate ceramic raw materials:

project	Results
Product range	Micron-sized tungstic acid, nano-sized tungstic acid, ultrafine spherical tungstic acid
Ceramic compatibility	Sintering compatibility with ZrO_2 , Al_2O_3 , TiO_2 systems > 90 %
Cooperation Cases	$_3 – Si_3N_4$ composite tool ceramics with many domestic ceramic factories
Process Platform	Establish a hydrogen/nitrogen sintering test line to meet the atmosphere requirements of special ceramics
Exit Direction	Tungsten acid powder for ceramics has been sold to Japan, South Korea, and Germany, and is mainly used for electrical ceramic substrates and optical glass fillers.

VII. Summary

As an important raw material for high-performance ceramics, tungstic acid not only shows significant material advantages in the fields of structural ceramics, functional ceramics and special ceramics, but its good process compatibility and modification potential also make it one of the strategic substances in the research and development of new ceramic materials. As ceramic materials change from durable to functional and intelligent, tungstic acid will play a more important role in the high-density, high-thermal-conductivity and strong-functional integrated ceramic material system.

6.4 The role of tungstic acid as a precursor in heat-resistant and corrosion-resistant coating materials

Tungsten acid (H_2WO_4) is a tungsten source compound with stable structure, high reactivity and convertibility into various oxidation states. It has shown important precursor value in the field of coating materials, especially in high-temperature oxidation resistance, corrosion protection, and coating systems in extreme service environments. Relying on its easy pyrolysis into high-performance tungsten oxides such as WO_3 and $W_{18}O_{49}$, tungsten acid has become an indispensable raw material basis for advanced functional coatings.

This section will focus on the application role of tungsten acid in high-temperature coatings, plasma sprayed ceramic coatings, chemical anti-corrosion coatings and optoelectronic protective coatings, analyze its material reaction mechanism, formation process path and performance contribution, and combine the practical cases of CTIA GROUP to demonstrate its industrial significance as a strategic precursor.

1. Core requirements of coating materials and compatibility of tungstic acid

Modern coating materials, especially in the fields of aerospace, nuclear industry, metallurgy, high-end manufacturing, etc., place stringent requirements on **the heat resistance** , **corrosion resistance** , **structural density** and **multifunctionality of materials** . Tungstic acid, as a precursor, can be converted into dense WO_3 film , high-stability WOM (metal) composite or porous W-based ceramic coating to meet the following engineering needs:

Key Requirements	Tungstate Precursor Effect
High temperature anti-oxidation	After decomposition, WO_3 / WO_2 is formed . 9 Protective layer blocks O_2 diffusion
Strong acid/alkaline corrosive environment	Tungstate coating has chemical passivation ability
Electric heating double protection	W^{5+} /W^{6+} state transition enhances electronic and thermal shielding properties
Structural Matching	Produces well-adherent coatings on a variety of substrates
Film Compatibility	Thin films can be formed by sol-gel, spraying, and ablation

2. Types and characteristics of tungstic acid-derived coating systems

1. Tungsten oxide (WO_3) heat-resistant protective coating

- Thermal decomposition of H_2WO_4 can directly form a uniform WO_3 film ;

- It has good thermal stability and oxidation resistance in the temperature range of 600-800°C ;
- Can be used alone or as a "bond layer" for ceramic coatings.

Features and advantages:

- High density and good compactness;
- The W^{6+} ion structure is stable and electrically neutral;
- It can be further reduced to form a conductive protective film.

2. Tungsten acid-metal oxide composite coating (W-MO_x)

- Mix tungstic acid with TiO_2 , ZrO_2 , SiO_2 , CeO_2 , etc .;
- Using synergistic structures to form composite ceramic coatings;
- It can significantly improve the thermal barrier effect and acid and alkali corrosion resistance.

Typical structure: WO_3 – ZrO_2 , WO_3 – SiO_2 , W–Ti composite layer.

3. Tungstate Vitrified Coating

- Tungstic acid is eutectic with glass precursor (B_2O_3 , P_2O_5 , etc.) ;
- After film formation, it has transparency, high hardness and chemical resistance;
- Used for photoelectric protective films and shielding coatings.

4. Electrochromic protective coating

- Tungstate -based materials have good electrochromic properties;
- Used for dimming, thermal control, and anti-reflective glass;
- Dynamic adjustment of thermal resistance/optical reflection can be achieved.

3. Preparation method and film forming process

1. Sol-Gel

- Tungstic acid, alcohols and complexing agents form a uniform sol;
- Coating, drying and heat treatment form a dense coating;
- Suitable for glass, ceramic and metal substrates.

2. Thermal decomposition method

- Heat (300–600°C) directly after coating with tungstic acid;
- Transformed into WO_3 layer ;
- Suitable for low-cost anti-oxidation scenarios.

3. Plasma spraying

- Pre-treating tungstic acid powder into sprayable slurry;
- High temperature spraying to form ceramic coating;
- Widely used in aerospace engine blades and nuclear reactor components.

4. Electrostatic spraying/spin coating

- Suitable for large area transparent film;
- Good film uniformity and low cost;
- Strong compatibility with flexible electrodes and photovoltaic devices.

4. Performance and key indicators

index	scope	illustrate
Heat resistant temperature	800–1100°C	WO_3 has a high stability structure retention rate
Acid and alkali resistance	pH 2–12 stable	Good passivation layer protection mechanism
Adhesion strength	> 8 MPa (ASTM)	Good adhesion, not easy to fall off
Thermal conductivity	2.5–3.0 W/ m·K	Adjustable thermal insulation performance
Light transmittance	> 70% (film type)	Can be applied to transparent thermal control coatings

5. Typical application areas and product cases

1. High temperature protective coating

- Application objects: aerospace engine casing, gas turbine components;
- Coating system: WO_3 – ZrO_2 / Al_2O_3 gradient coating;
- ^{4} cycles of heat shock at 1100°C .

2. Chemical industry corrosion resistant layer

- Application objects: sulphuric acid tower lining, chlor-alkali equipment, waste gas absorption tower;
- Coating system: W–Ti–Si vitrified coating;
- Performance: Stable operation in 12% sulfuric acid for more than 5000 hours.

3. Electro-optical functional coating

- Application objects: architectural glass, car HUD, smart windows;
- Coating system: W–ITO–PVA composite color-changing coating;
- Performance: The transmittance adjustment range in the visible light region is 30%, and the response time is <2s.

4. Nuclear industry and radiation protection

- Application objects: neutron moderator, high Z protection screen;
- Coating system: tungsten acid composite tungsten copper coating ;
- Performance: Effectively reduces gamma rays and has excellent resistance to neutron corrosion.

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VI. CTIA GROUP Practice and Engineering Transformation

Modules	Implementation content	Industrialization achievements
Coating material system	Developed industrial grade tungstic acid/tungstate powder	Particle size 200nm–2μm, suitable for spraying system
Process Development	Establish three platforms: spin coating, pyrolysis, and spraying	Supports multi-substrate coating and heat treatment
Product System	Launched WO_3 - TiO_2 high temperature protection paste and tungstate glass powder	Applied in aerospace, electronic packaging, chemical reaction equipment
Application Development	Cooperate with glass factories and battery factories to develop transparent coatings	Initially achieved mass supply and overseas export

VII. Summary

As a precursor, tungsten acid plays a key role in heat-resistant and corrosion-resistant coating material systems. It not only provides an effective barrier for extreme conditions such as high temperature, corrosion, and radiation, but also improves the multifunctional integration level of coating materials through structural design and composite engineering. With its excellent process adaptability and material compatibility, tungsten acid coatings have been widely used in aerospace, energy, chemical industry, construction and other fields. In the future, it will continue to expand its engineering boundaries and industrial value in green materials, intelligent protection and high-end manufacturing.

Tungstic Acid Introduction
CTIA GROUP LTD

1. Tungstic Acid Overview

The tungstic acid (tungsten trioxide hydrate, $WO_3 \cdot H_2O$) produced by CTIA GROUP LTD is a high-purity yellow crystalline powder, manufactured using advanced precipitation and calcination processes. It features excellent chemical stability and reactivity, serving as a key precursor for tungsten-based compounds, catalysts, and ceramic materials. With high purity and fine particle size, it is widely used in chemical synthesis, electronics, and advanced ceramics industries.

2. Tungstic Acid Features

- Chemical Formula: $WO_3 \cdot H_2O$
- Molecular Weight: 249.85
- Appearance: Yellow crystalline powder
- Melting Point: Decomposes >100°C
- Density: 5.5 g/cm³
- Stability: Stable under dry conditions, decomposes in water to form tungstate ions, requires sealed storage
- Wide Applications: Used in catalyst preparation (selectivity >95%), tungsten oxide synthesis, ceramic pigments

3. Tungstic Acid Product Specifications

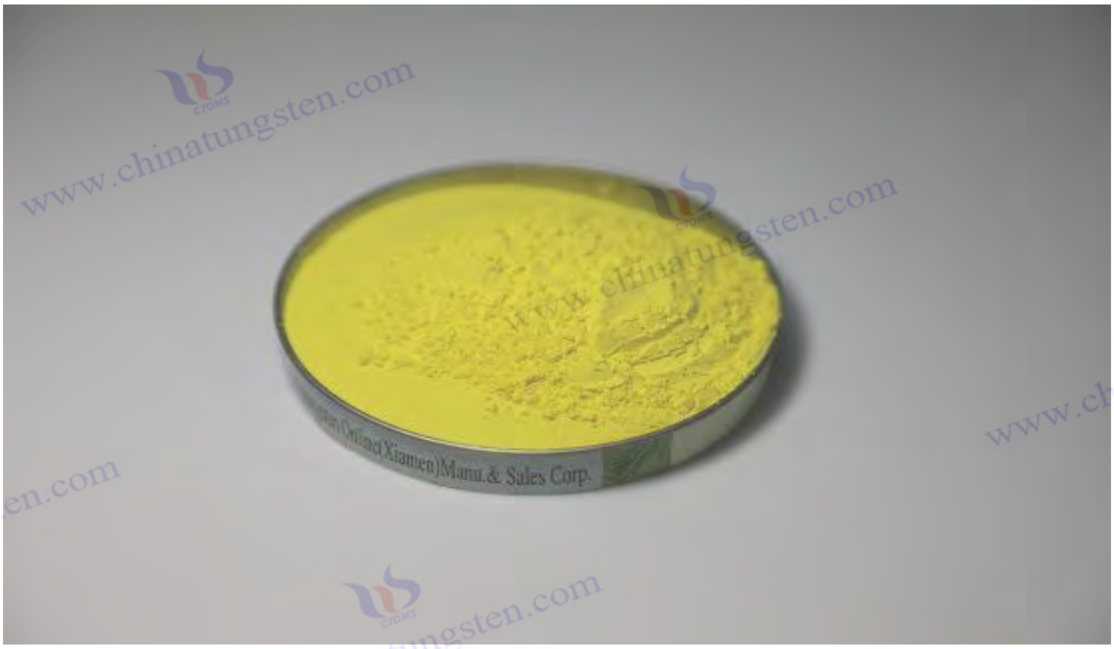
Grade	Purity (wt%)	Particle Size (μm)	Solubility	Impurities (ppm)
Reagent Grade	≥99.9	1–10	Slightly soluble	Fe≤10, Na≤5, Si≤10
Industrial Grade	≥99.5	1–10	Slightly soluble	SO_4^{2-} main, trace elements
Technical Grade	≥98.5	1–10	Slightly soluble	Minor oxide impurities allowed

4. Tungstic Acid Packaging and Quality Assurance

- Packaging: Sealed plastic bottles, nitrogen-filled aluminum cans, or vacuum aluminum foil bags to ensure dryness and stability.
- Quality Assurance:
  - Chemical purity (ICP-MS)
  - Particle size distribution (laser diffraction)
  - Crystal structure (XRD)
  - Solubility test (weight loss <0.1% in water)

5. Tungstic Acid Procurement Information

- Email: sales@chinatungsten.com
- Phone: +86 592 5129595
- Website: http://tungstic-acid.com



Chapter 7: Application of Tungstic Acid in Functional Materials and Energy Fields

7.1 Application of tungstic acid in photocatalytic materials (degradation of pollutants, etc.)

Photocatalytic materials are a type of functional materials that can absorb light energy and convert it into chemical energy. They are widely used in the fields of organic pollutant degradation, water purification, air treatment, antibacterial and anti-virus, and photocatalytic water splitting to produce hydrogen. Tungstic acid (H_2WO_4) and its derivatives have become promising inorganic catalytic platform materials in the field of photocatalysis due to their excellent optical band gap structure, good photogenerated carrier behavior, stable chemical properties and structural adjustability.

This section will comprehensively introduce the basic performance advantages of tungstic acid as a photocatalytic material, the photocatalytic reaction mechanism, modification and composite strategies, typical application cases, as well as current research hotspots and future development directions.

1. Basics of Tungstic Acid Photocatalytic Properties

1. Band structure and photoresponse characteristics

Tungstic acid and its oxidized derivatives (such as WO_3 , $W_{18}O_{49}$) have wide bandgap semiconductor properties:

Material	Band gap (Eg)	Light response range
H_2WO_4	2.6–2.8 eV	Near ultraviolet to blue light region
WO_3	2.5–2.7 eV	UV to Visible (<480 nm)
$W_{18}O_{49}$	2.3–2.6 eV	Enhanced visible light response

These band gap ranges enable them to effectively absorb high-energy portions of the solar spectrum, generate electron-hole pairs, and induce redox reactions.

2. Brief description of catalytic mechanism

Typical photocatalytic reaction pathways include:

1. Light excitation produces electrons (e^-) and holes (h^+);
2. e^- participates in the reduction of O_2 to form superoxide radicals ($\cdot O_2^-$), and h^+ participates in the oxidation of water to form hydroxyl radicals (·OH);
3. Free radicals attack organic pollutants and degrade them into CO_2 and H_2O .

$$H_2WO_4 + hv \rightarrow e^- + h^+$$
$$e^- + O_2 \rightarrow \cdot O_2^-$$
$$h^+ + H_2O \rightarrow \cdot OH + H^+$$

2. Types and modification strategies of tungstate-based photocatalytic materials

1. Crystal form control

By controlling pH, temperature, reactants, etc. , different crystal forms (orthorhombic, monoclinic, triclinic, etc.) of tungstic acid can be obtained, and its crystal structure directly affects the band gap width and charge migration rate.

- Orthogonal phase: high transmission rate and excellent photocatalytic performance;
- Monoclinic phase: suitable for composite modification and improved light response.

2. Doping and defect engineering

- **Metal doping** : such as Ag^+, Cu^{2+}, Fe^{3+}, etc., to construct impurity energy levels and expand light absorption;
- **Non-metal doping** : such as N, S, C, etc., to improve the lifetime of photogenerated carriers;
- **Oxygen vacancy regulation** : Introducing O vacancies as reaction active centers to enhance visible light catalytic activity.

3. Construction of heterojunction composite materials

By combining with other semiconductors, Z-type, I-type, and pn heterojunctions can be constructed to improve charge separation efficiency:

- **TiO_2 / H_2WO_4 : Enhanced UV** response;
- **gC_3N_4 /WO_3 : Construction of visible light** Z-type catalytic system **;**
- **$BiVO_4$ /WO_3** : Improve water oxidation efficiency and electron migration rate;
- **WO_3 / Ag@AgCl : achieving plasmon resonance** enhanced catalysis.

3. Practical application areas and material performance

1. Degradation of organic pollutants

- Tungstic acid materials can effectively degrade methyl orange (MO), rhodamine B (RhB), phenol, tetracycline, epichlorohydrin, etc.
- The degradation efficiency can reach over 90% under simulated sunlight or visible light.
- The material has good stability and there is no significant performance degradation after more than 5 cycles.

2. Water purification and wastewater treatment

- Tungstic acid – TiO_2 complex is widely used in dye wastewater treatment;
- Nano WO_3 coating is suitable for anti-biological fouling and decolorization treatment in industrial circulating water systems;
- A fixed-bed photocatalytic reactor is constructed with activated carbon, zeolite, MOF and other loads.

3. Air purification and VOCs control

- Tungstic acid catalyst can degrade indoor pollutants such as formaldehyde, benzene, and TVOC;
- Applied to photocatalytic filters, coatings, and air purifier core materials ;
- A low-temperature and low-light-intensity response system can be constructed, which is suitable for indoor light environments.

4. Antibacterial photocatalytic surface coating

- Tungstate-based photocatalytic films release ·OH and $\cdot O_2^-$ under visible light , destroying bacterial cell walls;
- of Escherichia coli, Staphylococcus aureus and Candida albicans is over 99%;
- Used in medical environments and antibacterial coatings on traffic contact surfaces.

4. Representative material systems and performance data

Material system	Light source type	Degradation object	Degradation efficiency
WO_3 / TiO_2	UV+Visible light	RhB (20 mg/L)	>95% in 60 min
gC_3N_4 / WO_3	Visible light	Methyl Orange	>90% in 90 min
Ag@WO_3	Sunlight simulation	phenol	>85% in 120 min
$W_{18}O_{49}$ nanorods	LED light source	Cyclopropylamine	>80% in 100 min
H_2WO_4 / Activated Carbon	Natural Light	Organic wastewater COD	70–85% reduction

5. Progress in R&D of CTIA GROUP Technology

CTIA GROUP has carried out systematic research on tungstate-based photocatalytic materials, covering the following dimensions:

direction	Technical content	Phase Achievements
Material preparation	Low-temperature liquid phase synthesis of high specific surface area tungstic acid	The surface area of tungstic acid in single crystal form can reach 125 m²/g

Structural modification	Construction of gC_3N_4 / WO_3 heterostructure	RhB degradation increased by 35%
Application System	Design of static and dynamic photocatalytic water treatment modules	Already deployed in a test line of a printing and dyeing factory in Fujian
Product Development	Developed tungstic acid coated air purification sheet	With high efficiency sterilization function, stable cycle life>300 hours

7.2 Research progress of tungstic acid in energy storage materials (supercapacitors, batteries)

In the context of coping with the energy crisis and developing green energy technology, the development of energy storage materials has become an important frontier of energy technology. Tungstic acid (H_2WO_4) has attracted extensive attention in recent years in energy storage fields such as supercapacitors and battery electrode materials due to its good electrochemical reversibility, structural diversity, rich redox active centers and high specific capacitance potential.

This section will focus on the action mechanism, synthesis method, modification strategy and application scenarios of tungstic acid and its oxidized derivatives in energy storage materials. Combining the latest research results and the practical progress of CTIA GROUP , it will present its development prospects in modern energy storage systems.

1. Basic properties of tungstic acid for energy storage materials

characteristic	Performance	Energy storage function
Reversible redox behavior	$W^{6+} \leftrightarrow W^{5+} \leftrightarrow W^{4+}$	Provides pseudocapacitive or capacitance response
Polymorphic structure	Monoclinic, triclinic, orthogonal, etc.	Regulate ion diffusion channels
High theoretical specific capacitance	>700 F/g (theoretical)	For supercapacitor material development
Structural stability	WO_3 /H_2WO_4high decomposition temperature	Suitable for high voltage window system
Good electrode compatibility	Strong composite properties with carbon, conductive polymers, etc.	Favorable for interface construction and electron migration

2. Application of tungstic acid and its derivatives in supercapacitors

Supercapacitors (SCs) are energy storage devices that use surface charge accumulation and pseudocapacitive reactions as energy storage mechanisms. Tungstate materials mainly play a role in pseudocapacitive devices because their W^{6+} / W^{5+} conversion process can participate in a fast and reversible Faradaic reaction.

1. Material system and performance

Material system	Synthesis method	Capacitor performance
H_2WO_4 nanosheets	Hydrothermal method	410 F/g (0.5 A/g)

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WO_3 nanorods	Sol-Gel Method	515 F/g (1 A/g)
$W_{18}O_{49}$ nanowires	Pyrolysis + Defect Engineering	621 F/g (0.2 A/g)
WO_3 / CNT composites	Solution blending + heat treatment	720 F/g (1 A/g)

2. Performance advantages

- Short response time: charging and discharging completed within <2s;
- Strong cycle stability: capacity retention rate >85% after 5000–10000 cycles;
- High power output: supports operation at high current density (>10 A/g);
- Wide operating voltage window (>1.2 V, water system);

3. Modification strategy

- **Conductivity enhancement** : compounded with graphene, CNT, carbon cloth, etc. to increase the electron migration rate;
- **Surface area regulation** : synthesis of porous, lamellar, and hollow structures to increase reaction sites;
- **Ion doping** : such as Mo^{6+}, V^{5+}, Mn^{2+}, to adjust the redox potential and charge transfer rate;
- **Polymer composite :** synergistically achieve dual functional response with PANI and PPy .

3. Research progress of tungstic acid in battery electrode materials

the development of electrode materials for lithium -ion batteries (LIB), sodium-ion batteries (SIB), magnesium-ion batteries and flexible micro-batteries due to their high electrochemical stability and reversible redox ability .

1. Tungstate-based lithium battery negative electrode material

- WO_3 can react with Li^+ to produce multi -electron reaction ($W^{6+} \rightarrow W^0$), with a high theoretical capacity (693 mAh /g);
- There is a certain volume expansion problem, but it can be overcome through nano-sizing and carbon composite;
- An initial capacity of >600 mAh /g can be achieved, and the capacity after cycling is stable at 400–500 mAh /g.

2. Exploration of tungstic acid in sodium ion batteries

- The sodium ion has a large radius, requiring a wider channel;
- Nano WO_3 or doped tungstate structure has excellent ion diffusion properties;
- The initial capacity is about 200–350 mAh /g, and the cycling stability is good.

3. Application in new battery systems

- **Solid-state battery interface materials** : WO_3 nanofilm improves interface stability;
- **All-solid-state flexible battery** : Tungstate composite electrolyte has good ionic conductivity and mechanical flexibility;

- **Microbatteries and energy chips** : Tungsten oxide nanoribbons can be used as ultra-small electrodes in flexible electronics.

IV. Practical Applications and Engineering Examples

Application Scenario	Material system	Performance characteristics
Industrial grade supercapacitor electrodes	WO_3 /Carbon cloth	High capacity, low impedance, easy to prepare
Flexible energy storage devices	H_2WO_4 / PPy / PVA composite electrode	Bendable, cycle life>10000 times
Fast charging power module	$W_{18}O_{49}$ /G composite nanoelectrode	Supports 60s full charge, high rate charge and discharge resistance
Power tools/UAV energy storage	WO_3 @CNT composite electrode	High rate output, excellent low temperature performance

5. Progress of CTIA GROUP Practice

CTIA GROUP has carried out multi-dimensional exploration around the industrialization of tungsten acid energy storage materials:

direction	Specific progress
Raw material development	Tungstate powder with layered structure (particle size 50–300 nm);
Process Platform	Construct an integrated production line of "nano-tungstic acid-carbon-based composite slurry-electrode sheet";
Industry Cooperation	Cooperate with universities to develop WO_3 /GO composite supercapacitors;
Application Scenario	Provide pilot samples for new energy vehicles and power grid peak load regulation systems;
Results	The company has been granted 7 patents related to tungstate-based energy storage materials, and 2 of them have entered the stage of achievement transformation.

VI. Research Hotspots and Future Development Directions

1. Tungsten Acid Energy Storage Material Structural Engineering

- Develop multi-level pore structures to improve electrolyte penetration and ion diffusion;
- Constructing hollow/core-shell/heterojunction type electrode particles to optimize cycling stability.

2. Multifunctional composite energy storage system

- Integrate the triple response functions of light, electricity and heat to achieve intelligent energy storage and allocation;
- Construct new composite energy storage materials such as tungstic acid- MXene and tungstic acid-MOF.

3. Large-scale preparation and low-cost process development

- Simplify hydrothermal, spray, and heat treatment paths;
- Promote the transition from industrial -grade materials to high-performance electronic -grade materials ;
- Integrated development with sodium batteries, lithium-sulfur batteries and all-solid-state batteries.

VII. Summary

Tungstic acid and its derivatives are becoming highly competitive members of the new energy storage material system due to their unique electrochemical properties, structural diversity and controllability. Its application in supercapacitors, battery electrodes and flexible energy storage devices is constantly advancing, and it also provides a new idea for the integration of new energy and electronic materials. In the future, tungstic acid is expected to play a core role in high energy density, long life, low-cost green energy storage technology.

7.3 Application of tungstic acid in electrochromic and optical control materials

Electrochromic materials are functional materials that can reversibly change their optical properties (such as color, transmittance, reflectivity, etc.) under an applied voltage. They are widely used in smart windows, electronic paper, displays, thermally regulated glass, etc. Tungstic acid (H_2WO_4) and its oxidized derivatives , especially tungsten trioxide (WO_3), have become one of the most mature and widely used inorganic electrochromic materials due to their excellent photoelectric response performance, good electrochemical stability and reversible ion intercalation behavior .

This section will comprehensively discuss the core mechanisms, material types, preparation processes, performance indicators and typical applications of tungstic acid and its related materials in electrochromic and optical regulation, and provide theoretical support and technical routes for the development of tungstic acid into intelligent optoelectronic materials.

1. Electrochromic principle and response mechanism of tungstate materials

1. Basic principles of electrochromism

Electrochromism refers to the reversible change of the optical properties of a material caused by the migration of electrons and ions in the crystal lattice under the action of an electric field. The main reaction process is:

WO3 + xM ++ xe −⇌ Mx WO3

Where M^+ is the inserted ion (H^+ , Li^+ , Na^+ , etc.). After intercalation, M_xWO_3 will change from colorless (or light blue) to dark blue or blue-purple, showing a color change.

2. Response characteristics of tungstic acid materials

- **The color changes significantly** : from colorless/light yellow → dark blue/dark gray;
- **Fast response speed** : intercalation reaction is rapid (<2s);

- **Strong reversibility** : can achieve tens of thousands of color change cycles;
- **Strong spectral control capability** : mainly acts in the visible light region, and can also be extended to the near infrared region;
- **Low energy consumption** : color changing state can be maintained without continuous power supply.

2. Types of electrochromic materials of tungstic acid and its derivatives

1. Crystalline WO_3 thin film

- Formed by thermal decomposition of H_2WO_4 or electrochemical deposition ;
- Good crystallinity and strong optical control;
- Suitable for applications in smart windows and anti-reflective films.

2. Hydrotungstic acid/amorphous WO_3 gel material

- Good flexibility, can be compounded with polymers;
- Used for curved devices and flexible displays.

3. Nanostructured tungstic acid materials

- Morphologies such as nanorods, sheets, and hollow spheres;
- Improve specific surface area and response rate;
- It helps to improve intercalation efficiency and cycle life.

4. Composite tungstic acid electrochromic material

- with TiO_2 , V_2O_5 , PEDOT, PANI, etc.;
- Build a multifunctional dimming material system.

3. Thin Film Preparation Process and Device Configuration

1. Film preparation method

method	Features
Sol-Gel Method	Low cost, suitable for large area coating, uniform film layer
Thermal decomposition method	crystallinity , suitable for preparing crystalline WO_3 film
Electrochemical deposition	Dense structure and controllable thickness
Sputtering	Strong film adhesion, suitable for multi-layer stacking structure
Spraying method	Rapid film formation, suitable for industrialization

2. Device configuration

The typical electrochromic device structure is:

Conductive glass/electrochromic layer (WO_3)/electrolyte layer/counter electrode layer (NiO)/conductive glass

Optional electrolytes: solid PVA/H_3PO_4 gel , Li^+ polymer , ionic liquid, etc.

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4. Performance Evaluation Indicators

index	scope	illustrate
Optical modulation amplitude (ΔT)	30–70% (at 633 nm)	Difference in light transmittance before and after discoloration
Coloring efficiency (CE)	40–120 cm²/C	Change in optical density per unit charge
Color change response time	Coloring <3s, bleaching <6s	The faster the better for dynamic dimming
Cyclic stability	>10,000 times without attenuation	Persistence Key Indicators
Energy consumption	<5 mW /cm²	Outstanding low power consumption advantage

5. Typical application areas

1. Smart Windows

- Control indoor light and heat to reduce air conditioning energy consumption;
- It has been used in high-end buildings, rail transit, and spacecraft windows;
- It can be integrated with photovoltaic cells and sensors to achieve automatic light changing.

2. Flexible electronic paper and low-power displays

- Tungsten acid film has high contrast and visibility;
- Building a curved reader with polymer electrolytes;
- Replace traditional LCD and LED in low power consumption scenarios.

3. Photoelectric protection and camouflage system

- Quick response to adjust reflectivity and shield thermal infrared;
- Military stealth, aviation windows, anti-laser protective coatings;
- Realize the integration of optical color change and thermal control functions.

4. Information display and anti-counterfeiting applications

- Constructing patterned color-changing layers and multi-layer responsive structures;
- Used for identity recognition, ticket anti-counterfeiting, interactive electronic tags, etc.

VI. CTIA GROUP Electrochromic Technology Development Practice

Modules	Implementation content	Phase Achievements
Raw material development	of highly dispersed H_2WO_4 and nano - WO_3 slurry	For low temperature thin film deposition process
Process Platform	Construction of sol-gel + pyrolysis combined film production line	Film uniformity better than ±5%, ΔT up to 60%
Device testing	of PVA/H_3PO_4 solid - state electrochromic devices	Color change cycle >15,000 times without attenuation

Application Development	Jointly develop smart window products with architectural glass companies	Sample testing has been completed and the trial launch phase has begun

7. Research Trends and Future Development Directions

1. Development of all-solid-state flexible devices

- Development of flexible electrodes (ITO-PET, silver nanowires) and solid gel electrolytes;
- Build a rollable, wearable smart visual system.

2. Multifunctional composite material design

- Combines energy storage, electroluminescence, and photothermal regulation functions;
- Construct composite systems such as WO_3 @CNT, WO_3 /PEDOT, etc.

3. Intelligent control system integration

- Integrate with sensors and light control modules to achieve environmental adaptive color change;
- Applied to the new platform of "Internet of Things + Smart Materials".

4. Long life and high stability development

- Improve interface matching and inhibit structural attenuation of intercalated materials ;
- Designing porous/ordered structures to buffer charge migration stress.

8. Summary

As electrochromic materials, tungstic acid and its oxidized derivatives have become one of the core materials in the field of intelligent dimming and optical regulation due to their efficient and reversible ion intercalation behavior , wide spectrum response ability and stable structural characteristics. With its integration with flexible materials, energy storage systems and intelligent control technologies, the tungstic acid electrochromic system will play a greater strategic role in green buildings, flexible electronics and intelligent optoelectronic integration.

7.4 Development of Nanotungstic Acid in Sensors and Self-cleaning Materials

Tungstic acid (H_2WO_4) has excellent optical, electrical and chemical stability, while its nanoscale derivative (nano - tungstic acid) has a higher specific surface area, stronger surface activity and faster reaction kinetics. In recent years, nano-tungstic acid has been widely used in environmental sensors, gas sensors, humidity detection, biometrics, self-cleaning coatings and anti-fog and anti-fouling materials, and has gradually become a functional platform for building a new generation of smart materials.

This section will focus on the performance advantages, material construction strategies, typical application forms of nano-tungstic acid materials in the field of sensors and self-cleaning, as well as CTIA GROUP 's research practices in this direction.

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1. Characteristics and functional advantages of nano-tungstic acid

property	describe	Application Value
High specific surface area	Nanoparticle size (10–100 nm), porous structure	Enhance the adsorption and recognition efficiency of analytes
Abundant surface oxygen vacancies	Adjustable electronic states and catalytic active centers	Favorable for gas-sensing, electro-sensing and photo-responsive behaviors
Strong light responsiveness	Can absorb ultraviolet and part of visible light	Stimulate self-cleaning and photocatalytic sterilization capabilities
Can be compounded with a variety of materials	Synergistic structure construction with CNT, GO, polymer, etc.	Improved sensing selectivity and stability
Good chemical stability	Acid and alkali corrosion resistance, high thermal stability	Suitable for long-term work in complex environments

2. Application of Nano-tungstic Acid in Sensor Field

1. Gas Sensor

Tungsten acid -based materials show high sensitivity and selectivity to a variety of gases (such as NH_3 , NO_2 , H_2S , ethanol, formaldehyde, etc.).

Working mechanism:

- Gas molecule adsorption → change resistance/current → signal output;
- Oxygen vacancies and W^{6+} /W^{5+} conversion play a role in regulating electron transport;
- Light-assisted sensing enhances response intensity and selectivity.

Representative materials and properties:

Material system	Targeting Gas	Detection limit	Response time
H_2WO_4 nanosheets	NH_3	0.2 ppm	<30s
WO_3 nanowires	NO_2	50 ppb	<10s
$W_{18}O_{49}$ @CNT	H_2S	0.1 ppm	<5s
WO_3 / rGO composite	Ethanol	1 ppm	<20s

2. Humidity and temperature sensors

- Tungstic acid is sensitive to the adsorption of water molecules and can be designed as a capacitive/resistive humidity sensor;
- It can be integrated for environmental monitoring, smart clothing, and health electronic patches.

3. Biosensing and electrochemical detection

- Nano-WO_3 complex is used for the detection of glucose, cholesterol, DNA, etc.;
- The surface can be functionalized with enzymes, antibodies, and aptamers;
- It can achieve high sensitivity and fast response, and has the potential to be used as a wearable medical device.

3. Development of Nano-tungstic Acid in Self-cleaning Materials

1. Overview of self-cleaning mechanism

The self-cleaning performance of nano-tungstic acid is mainly achieved through the synergy **of photocatalytic degradation** and **super-hydrophilic surface effect** :

- **Photocatalysis** : Under ultraviolet or visible light, active species such as OH are generated to decompose organic pollutants;
- **Super hydrophilicity** : water droplets spread to clean surface dust and oil;
- **Antibacterial property** : Reactive oxygen free radicals can kill bacteria and viruses.

2. Material system and functional characteristics

Material system	Symptoms	Application Examples
WO_3 film	Strong light response and transparent	Self-cleaning glass curtain wall
H_2WO_4 / SiO_2 composite	Nano-roughness + photocatalysis	Car rearview mirror anti-fog
$W_{18}O_{49}$ nanorods	Visible light response	Medical clean surface antibacterial coating
WO_3 / TiO_2 composite film	Synergistic catalytic effect	Photovoltaic panel dust-proof coating

3. Film formation and construction methods

- **Spin coating/spray coating** : suitable for glass, ceramic and plastic substrates;
- **Sol-gel method** : control film density and surface energy;
- **Electrophoretic deposition** : constructing large-area uniform film layers;
- **Template-assisted method** : generating micro-nanoscale porous rough surfaces.

4. Comprehensive application examples and scenario expansion

Application Scenario	Material system	Key Features
Smart Mask	Nano-tungstic acid/PVA composite film	Gas detection + antimicrobial protection
Smart Buildings	Tungstic acid self-cleaning glass	Light control and light transmission + anti-fouling and dust removal
Smart Wearable Devices	Nano WO_3 thin film sensing layer	Humidity/sweat sensing and physiological monitoring
Medical Surface Materials	Nano-tungstic acid antibacterial coating	Antibacterial + photocatalyst self-cleaning dual functions
auto industry	Rearview mirror anti-fog film	Rapid hydrophilicity + strong weather resistance

5. CTIA GROUP Research and Industrial Transformation

CTIA GROUP has carried out in-depth layout in the field of nano-tungstic acid sensing and self-cleaning materials:

direction	Implementation content	Phase Achievements
Raw material system	Nano-tungstate powder particle size is controlled to 20–100 nm	Available in batches for spraying/coating
Composite material development	WO_3 @TiO_2 , WO_3 @GO, WO_3 @PVA , etc.	Achieving integration of multifunctional materials
Product Launch	Launched nano-tungstic acid self-cleaning glass precursor solution	Suitable for architectural/traffic glass coating
Sensor Module	Cooperate with scientific research institutions to develop NO_2 sensing film modules	Achieve ppm-level gas detection within <30 seconds
intellectual property	6 patents related to nano-tungstic acid functional materials have been applied for and authorized	

VI. Development Trends and Research Focus

1. Development of multi-parameter intelligent perception platform

- Integrates multiple functions such as temperature, gas, humidity, etc.
- Integrate with AI perception chips to achieve environmental adaptive feedback.

2. Wearable and flexible sensor material design

- Use flexible substrates such as PVA, PDMS, and polyimide;
- Build tungstate-based flexible sensor arrays to serve the field of health monitoring.

3. Self-cleaning and antibacterial integrated surface construction

- Strengthen the photocatalytic bactericidal ability and improve the durability of the film layer;
- Combined with anti-fog, anti-dust and anti-UV functions, the development of "full-scene surface materials" is realized.

4. Environmentally friendly coatings and green synthesis technology promotion

- Use non-toxic precursors and water-based processes to replace traditional organic solvents;
- Reduce coating film-forming temperature and energy consumption to meet industrial environmental protection requirements.

VII. Summary

As a new type of material with controllable structure, diverse functions and stable performance, nano-tungstic acid is playing an important role in the field of sensors and self-cleaning technology. Its excellent photoelectric activity, surface chemical behavior and material adaptability make it an indispensable component of smart materials, green coatings and smart wearable devices. In the future, with the continuous deepening of tungstic acid material design and interface construction technology, it will show greater potential in the fields of smart environment, personalized medicine, smart transportation and green buildings.

Tungstic Acid Introduction
CTIA GROUP LTD

1. Tungstic Acid Overview

The tungstic acid (tungsten trioxide hydrate, $WO_3 \cdot H_2O$) produced by CTIA GROUP LTD is a high-purity yellow crystalline powder, manufactured using advanced precipitation and calcination processes. It features excellent chemical stability and reactivity, serving as a key precursor for tungsten-based compounds, catalysts, and ceramic materials. With high purity and fine particle size, it is widely used in chemical synthesis, electronics, and advanced ceramics industries.

2. Tungstic Acid Features

- Chemical Formula: $WO_3 \cdot H_2O$
- Molecular Weight: 249.85
- Appearance: Yellow crystalline powder
- Melting Point: Decomposes >100°C
- Density: 5.5 g/cm³
- Stability: Stable under dry conditions, decomposes in water to form tungstate ions, requires sealed storage
- Wide Applications: Used in catalyst preparation (selectivity >95%), tungsten oxide synthesis, ceramic pigments

3. Tungstic Acid Product Specifications

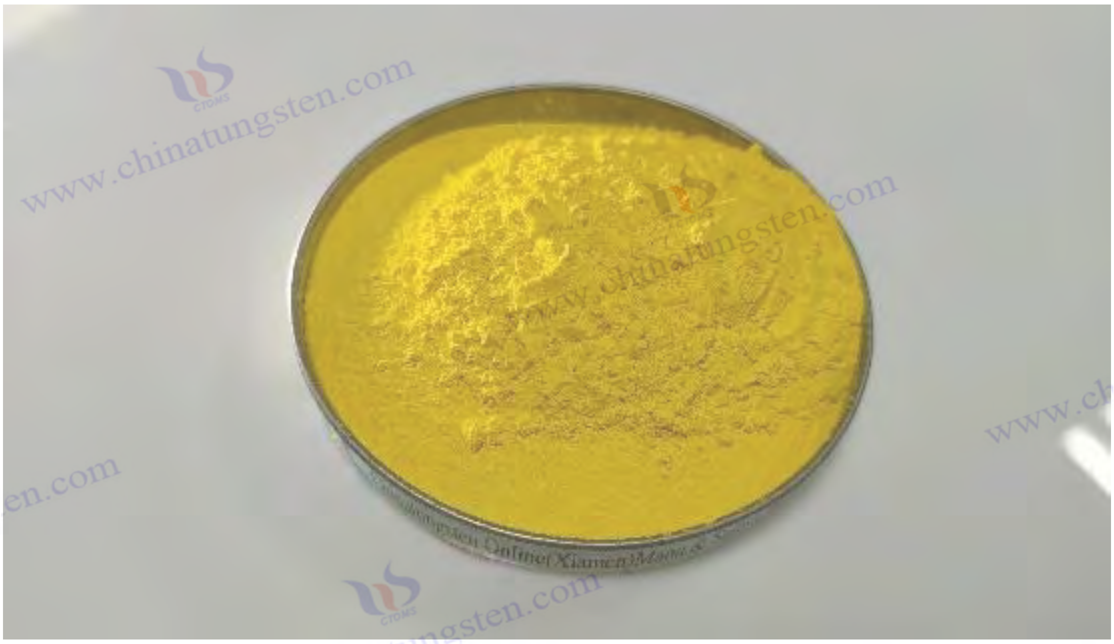
Grade	Purity (wt%)	Particle Size (μm)	Solubility	Impurities (ppm)
Reagent Grade	≥99.9	1–10	Slightly soluble	Fe≤10, Na≤5, Si≤10
Industrial Grade	≥99.5	1–10	Slightly soluble	SO_4^{2-} main, trace elements
Technical Grade	≥98.5	1–10	Slightly soluble	Minor oxide impurities allowed

4. Tungstic Acid Packaging and Quality Assurance

- Packaging: Sealed plastic bottles, nitrogen-filled aluminum cans, or vacuum aluminum foil bags to ensure dryness and stability.
- Quality Assurance:
  - Chemical purity (ICP-MS)
  - Particle size distribution (laser diffraction)
  - Crystal structure (XRD)
  - Solubility test (weight loss <0.1% in water)

5. Tungstic Acid Procurement Information

- Email: sales@chinatungsten.com
- Phone: +86 592 5129595
- Website: http://tungstic-acid.com



Chapter 8: Application of Tungstic Acid in Analytical Chemistry and Reagents

8.1 Tungstic acid as a colorimetric agent and titration reagent

Tungstic acid (H_2WO_4) and its various salt derivatives have a long history of application in analytical chemistry. Especially in color development reaction, complexometric titration, colorimetric determination and ion quantification, tungstic acid can form stable multi-nuclear or complex structures with various cations and show significant color changes. Therefore, it is often used as an analytical reagent, color developer and titration auxiliary component.

This section will systematically review the classic applications of tungstic acid in traditional analytical chemistry systems, introduce its color development mechanism, its mode of action in the titration system, its combination with other reagents, and the need to optimize its performance in modern colorimetric analysis.

1. Basic mechanism and types of tungstate as a color developer

1. Principle of color reaction

Tungstic acid has strong coordination ability and can form distinctive and stable **heteropolyacid complexes** (such as phosphotungstic acid, silicotungstic acid, etc.) with certain metal ions (such as phosphate, arsenate, silicate, germanate, etc.) under acidic conditions, showing blue, yellow, green and other colors, which can be used for colorimetric analysis.

For example:

$12WO3 + H3\ PO4 + H2\ O \rightarrow H3\ [\ PW12\ O40\ ]$

tungsten blue under the action of reducing agent , which is suitable for visible light colorimetric determination.

2. Common tungstate color development system

Color rendering system	Targeted ions/substances	Generate Color	application
Phosphotungstic acid	PO_4^{3-}	Blue/Green	Water quality phosphorus content testing
Silicotungstic acid	SiO_3^{2-}	Yellow Green	Silicate analysis
Arsenic Tungstate	AsO_4^{3-}	Sky blue	Environmental Monitoring
Germanium tungstate	GeO_2	Blue Purple	Soil analysis

3. Color generation mechanism

The above color development reaction belongs to the heteropolyacid formation reaction. Through the coordinated coordination of multiple [WO_6] octahedra and central ions (such as P, Si, As), a Keggin -type structure is formed, and then charge transfer occurs, resulting in the appearance of color.

2. The role of tungstic acid as a titration auxiliary reagent

Tungstic acid is often used in titration analysis as:

- **Masking agent** : prevent interference with metal ion reactions;
- **Auxiliary complexing agent** : improve the selectivity of complexometric titration;
- **Redox regulator** : regulates solution potential and reaction direction.

1. Tungstic acid in quantitative titration of antimony, arsenic and other elements

- $^{+}$) in samples ;
- Arsenic tungstate complex is formed , and the endpoint is determined by the color change at the titration endpoint;
- It is commonly used as an auxiliary standard system in the molybdenum blue method or tungsten blue method.

2. Combined titration system

Tungstic acid is often used in combination with the following reagents for specific titration systems:

Combined reagents	Titration type	Target component
EDTA	Complexometric titration	Ca^{2+}, Mg^{2+}, etc.
Stannous chloride	Reduction titration	Fe^{3+}, Cr^{6+}
Phthalic acid	Acid-base titration masking agent	Interfering ions such as Al^{3+}

Tungstic acid plays a role in selectively masking or adjusting the acidity in such systems, thus improving the accuracy and sensitivity of titration.

3. Typical color analysis experimental plan

1. Colorimetric determination of phosphorus (tungsten blue method)

Principle : Under acidic conditions, phosphate reacts with tungstic acid to form phosphotungstic acid, which is then reduced by a reducing agent (such as sulfurous acid, ascorbic acid) to form a blue complex.

step :

1. Add H_2WO_4 reagent ;
2. Control pH to 0.2–1.0;
3. adding a reducing agent;
4. The absorbance was measured at a wavelength of 700–880 nm.

advantage :

- High sensitivity;
- Easy to operate;
- It can be applied to surface water, drinking water and sewage analysis.

2. Colorimetric determination of silicon (silicotungstic acid method)

- Tungstic acid reacts with silicate to form a yellow-green silicotungstic acid complex;
- The sensitivity was improved by using n-butanol extraction ;
- Applied to the analysis of cement, minerals, glass raw materials, etc.

4. Preparation and use conditions of tungstate analysis reagent

1. Tungstate reagent formula (typical)

Recipe ingredients	content	illustrate
Tungstic acid (H_2WO_4)	10–15 g/L	Original tungsten source
Hydrochloric acid or sulfuric acid	Control pH <1	Ensure the acidity of the reaction
Reducing agents (such as $NaHSO_3$)	Moderate	For color reaction

2. Storage and stability

- The prepared tungstate reagent should be sealed and protected from light;
- It can be stored stably at room temperature for 7-10 days;
- The product should be used immediately after adding the reducing agent to avoid color drift.

3. Notes

- Tungstic acid is a strong acid system, so please pay attention to safety when operating it;
- The color reaction is extremely sensitive to pH and needs to be precisely controlled;
- Impurity ions (such as Mo^{6+} and V^{5+}) may interfere with the color reaction and need to be removed by pretreatment.

5. CTIA GROUP Reagent Products and Application Expansion

CTIA GROUP has developed a series of standardized products in the field of tungstic acid analytical reagents, including:

Product Name	form	Typical Uses
Analytical grade tungstic acid (≥99.9%)	powder	Routine laboratory preparation
Phosphotungstic acid standard colorimetric solution	liquid	Rapid colorimetric quantification
Tungstate Derivative Masking Agent	Solid or solution	Titration auxiliary reagent system
Silicotungstic Acid Test Kit	Industrial reagent kit	Cement/Silica Material Analysis

We also cooperate with many university laboratories to promote the development of micro-analysis of tungstic acid reagents and nano-colorimetric devices.

VI. Research Hotspots and Future Development Directions

1. New system for micro/trace detection

- Tungstic acid is combined with sensitive materials such as nano-gold and quantum dots to construct a highly sensitive colorimetric method;
- Applied to food safety, heavy metal trace analysis, etc.

2. Improvement of solid phase and sensor

- The tungstate color developer is loaded on a paper substrate, a membrane substrate, or a microfluidic platform;
- Develop portable sensor chips and rapid test cards.

3. Development of intelligent colorimetric system

- Combined with mobile phone APP recognition technology, digital colorimetric analysis can be realized;
- The AI model is used to analyze the tungstic acid color spectrum to achieve multi-component identification.

VII. Summary

As an important inorganic reagent in analytical chemistry, tungstic acid has long played a core role in color development reactions and titration systems. By reacting with a variety of target ions to form complexes with significant colors, tungstic acid has not only improved the sensitivity of colorimetric analysis, but also expanded the technical boundaries of inorganic chemistry in quantitative detection. With the development of materials science and information analysis technology, tungstic acid reagents are moving towards intelligence, high throughput, and multifunctionality, and continue to expand their application value in modern analytical science.

8.2 Coordination of Tungstic Acid in Spectroscopic Analysis

In modern analytical chemistry, spectroscopic techniques (such as UV-visible spectroscopy, infrared spectroscopy, fluorescence spectroscopy, Raman spectroscopy, atomic absorption spectroscopy, etc.)

have become important tools for qualitative and quantitative analysis of substances. Tungstic acid (H_2WO_4) and its derivatives can form stable complexes with a variety of inorganic and organic components due to their high electronegativity, strong coordination ability and structural characteristics that can participate in charge transfer, playing an important role in signal enhancement, selective recognition and detection limit reduction in spectral analysis.

This section will systematically analyze the behavior mechanism, typical coordination structure and spectral response changes of tungstic acid as a ligand or precursor in various spectroscopic techniques , and introduce its specific applications in trace ion detection, environmental monitoring, bioanalysis and material identification.

1. Coordination properties and spectral response basis of tungstate

1. Structure and coordination characteristics of tungstic acid

Tungstic acid mainly uses [WO_6] octahedral structure as the basic unit and has the following characteristics:

- Aggregate structures can be formed by sharing vertices, edges or faces;
- It can form stable complexes with coordinating atoms such as O, N, S, and P;
- Can participate in multi-center metal complexes, such as polyoxotungstates .

2. Types of spectral changes caused by coordination

Spectral type	Coordination	Typical manifestations
Ultraviolet-Visible (UV-Vis)	Charge transfer, dd transition changes	Absorption wavelength red-shifted/blue-shifted, absorbance enhanced
Infrared spectroscopy (IR)	Bond length changes, vibrational energy levels change	Characteristic peak position shift or intensity change
Fluorescence spectrum	Energy level structure regulation	Emission wavelength shift, quantum yield enhancement
Raman spectroscopy	Changes in group symmetry	Raman activity is enhanced, and new characteristic peaks appear
Atomic Absorption	Improved atomization and dispersion behavior after coordination	Improved sensitivity, reduced interference

2. Coordination Enhancement of Tungstic Acid in UV-Vis Spectroscopic Analysis

1. Charge transfer band caused by polyacid complexation

reacts with various ions (such as PO_4^{3-} , SiO_3^{2-} , AsO_4^{3-} , etc.) under acidic conditions to form heteropolyacid structures (Keggin type, Dawson type , etc.), producing charge transfer absorption bands in the range of 250–800 nm, which are particularly suitable for colorimetric detection.

Typical reaction:

$$12WO_3 + H_3PO_4 + H_2O \rightarrow H_3[PW_{12}O_{40}]$$

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- The absorption band of the unreduced state is at 200–250 nm (light color);
- The "tungsten blue" generated after reduction has a strong absorption band of 600–700 nm.

2. Organic ligand enhanced color development system

- Tungstic acid forms conjugated complexes with organic molecules such as benzidine and phenols;
- The absorption wavelength of the complex is red-shifted, and the visible absorption peak is enhanced;
- It can be used for quantitative analysis of organic matter or structure-activity relationship analysis.

3. Coordination recognition of tungstate in infrared spectrum

1. Characteristic vibration peak

WO_3 or H_2WO_4 often show the following characteristic absorption in infrared spectrum:

- W=O stretching vibration: 880–950 cm^{-1};
- W–O–W bridge bond vibration : 600–800 cm^{-1};
- O–H stretching vibration (tungstate hydrate): 3200–3400 cm^{-1}.

Coordination causes changes in these peak positions, which can be used to determine whether the metal ion or organic ligand has successfully bound.

2. Identification of heteropolyacid complexes

Heteropolyacids (such as phosphotungstic acid and silicotungstic acid) have multiple sharp absorption peaks in IR (400–1200 cm^{-1}), the positions and intensities of which can be used to qualitatively identify the type and structural symmetry of heteropolyacids.

4. Function of Tungstic Acid in Fluorescence Spectroscopy Analysis

1. Tungstate fluorescence enhancement/quenching

- Tungstate as a ligand can regulate the fluorescence emission of rare earth ions (such as Eu^{3+}, Tb^{3+});
- Emission intensity enhancement is achieved through an energy transfer process;
- It can produce fluorescence quenching when it interacts with certain fluorescent dyes and can be used for metal ion detection.

2. Application Examples

Detection object	**Fluorescence system**	**Tungstate effect**
Fe^{3+}	CdTe - WO_3 composite quantum dots	Quenching fluorescence for trace iron detection
Cu^{2+}	Rhodamine–WO_4^{2-} complex	Fluorescence Enhanced Colorimetric Determination of Copper

DNA	$Ru(bpy)_3^{2+}$–tungstate complex	Fluorescence enhancement for nucleic acid detection

5. The auxiliary role of tungstic acid in atomic absorption and emission analysis

In AAS (atomic absorption spectroscopy) and ICP (inductively coupled plasma emission spectroscopy), tungstic acid can improve the accuracy of measurements in the following ways:

- Pre-form a complex with the metal ions to be tested to improve atomization efficiency;
- Reduce matrix interference and signal drift;
- As a releasing agent, it releases the complexed or precipitated ions to be analyzed.

For example, in the detection of strontium, lead, and barium, the tungstate coordination reaction can significantly reduce background interferences such as aluminum and silicon.

6. Typical coordination systems and analysis examples

Measured components	Coordination form	Analytical methods	Detection limit
PO_4^{3-}	$H_3[PW_{12}O_{40}]$	UV-Vis Colorimetry	0.01 mg/L
SiO_3^{2-}	$H_4[SiW_{12}O_{40}]$	UV-Vis Colorimetry + IR	0.03 mg/L
Fe^{3+}	WO_3 nano -fluorescence quenching	Fluorescence spectrum	0.005 mg/L
Bi^{3+}	Bi–WO_4^{2-} complex	ICP-OES	0.002 mg/L

VII. Materials and Technology Applications of CTIA GROUP

CTIA GROUP combines spectral analysis and material preparation to develop a series of analytical grade tungstic acid products:

Product Name	form	Application
High purity H_2WO_4 (99.99 %)	powder	Heteropolyacid colorimetric reagent
Nano WO_3 sol	Liquid dispersion	Fluorescence/UV absorption enhancement materials
Heteropoly Acid Reagent Kit	Powder/Liquid	Colorimetric analysis standards for teaching and research
WO_3 /GO composite probe	Film or slurry	Can be used for spectral sensor development

In addition, CTIA GROUP has cooperated with universities to develop a prototype of WO_3- based colorimetric sensor chip and is exploring its potential for on-site application in water quality monitoring and environmental emergency analysis.

8. Research Frontiers and Future Directions

1. Construction of multifunctional spectrally responsive materials

- Construct a composite system with UV, IR and fluorescence responses;
- Applied to multi-component synchronous detection platform.

2. Development of spectrally enhanced nanoprobes

- Combining tungstic acid with SERS (surface enhanced Raman spectroscopy);
- Used for detection of trace pollutants, poisons or biomarkers.

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3. AI-assisted spectral recognition system

- The characteristic spectrum formed by tungstate coordination;
- Rapid, high-throughput identification and quantification through artificial intelligence algorithms.

IX. Summary

Tungstic acid and its various coordination forms are not only used as auxiliary reagents in spectral analysis, but also as structural functional ligands widely used in colorimetry, infrared fingerprint recognition, fluorescent probe construction and atomic analysis systems. Its high coordination ability, charge transfer characteristics and broad spectrum response ability provide a rich reaction system and technical platform for analytical chemistry, and also provide a solid foundation for the future development of multi-dimensional spectral intelligence.

8.3 Function of Tungstic Acid in Heavy Metal Detection and Separation

Heavy metal pollution has long plagued the fields of industrial wastewater treatment, environmental protection and food safety supervision. Tungstic acid (H_2WO_4) and its various tungstate derivatives, due to their structure containing adjustable oxygen-bridged octahedrons, high electronegativity and good complexing ability, show excellent selective recognition and binding ability of metal ions, especially in the detection, separation and enrichment of heavy metal ions such as lead (Pb^{2+}), mercury (Hg^{2+}) , copper (Cu^{2+}) , cadmium (Cd^{2+}), showing broad application prospects.

This section will focus on the material properties, detection mechanism, separation pathways and practical applications of tungstic acid in heavy metal analysis and purification, providing theoretical support for its subsequent in-depth utilization in green analysis and resource recovery.

1. Coordination and recognition characteristics of tungstate and heavy metal ions

1. Structural advantages and metal bonding capabilities

$_6$] octahedral structure of tungstate has the following heavy metal binding characteristics:

characteristic	Performance	App Features
Multi-tooth coordination ability	Can form W–O–M bridge bonds	Stable binding of metal ions
Surface rich in hydroxyl groups/O^{2-}	Easy to exchange with M^{2+} ions	Favorable for adsorption and precipitation reactions
Can form heteropoly acid structure	Construction of M–W complex	Significantly enhanced selectivity
Adjustable band structure	Conducive to enhanced electrochemical detection	Functionalization of electrode materials

2. Targeted metal ions

Tungstic acid materials have significant recognition/binding ability to the following metal ions:

- High affinity: Pb^{2+}, Cd^{2+}, Hg^{2+};
- Medium affinity: Cu^{2+}, Zn^{2+}, Ni^{2+};
- Polyvalent metals: Cr^{3+}/Cr^{6+}, As^{3+}/As^{5+} (coordinated by heteropoly acids).

2. Application of tungstic acid in heavy metal ion detection

1. Colorimetric Detection

Tungstic acid forms a visible light absorbing complex with heavy metal ions to achieve a color reaction:

ion	Color product	λmax	Limit of Detection (LOD)
Pb^{2+}	Pb – H_2WO_4 complex	540 nm	0.005 mg/L
Cu^{2+}	Cu–WO_4^{2-} complex	580 nm	0.01 mg/L
Hg^{2+}	Hg–W heteropoly acid structure	600 nm	0.002 mg/L

Advantages:

- The color is obvious and easy to observe with naked eyes;
- Suitable for portable testing or test strip development.

2. Electrochemical detection

Modify the electrode surface with tungstic acid or its complex to construct a heavy metal electrochemical sensor:

- Tungstic acid/graphene (WO_3 @ rGO) modified glassy carbon electrode for detection of Pb^{2+} and Cd^{2+};
- WO_3 nanosheets /carbon cloth composite for voltammetric detection of Hg^{2+};
- The detection limit can be as low as ppb level, and the response time is less than 10 seconds, which is suitable for rapid on-site detection.

3. Selective separation and enrichment of heavy metal ions using tungstate materials

1. Separation mechanism of precipitation method

- Tungstic acid can form insoluble precipitates with some metal ions under acidic or neutral conditions;
- For example, Pb^{2+}, Cd^{2+} and WO_4^{2-} form $PbWO_4$, $CdWO_4$;
- These precipitates are heat stable, filterable, and suitable for pretreatment enrichment.

Example reaction:

$Pb2++WO4^{2-} \rightarrow PbWO4\downarrow$

2. Selective adsorption and exchange

By regulating the structure of tungstate materials (such as surface hydroxyl groups, oxygen vacancies, crystal form, etc.), the preferential adsorption of certain types of ions can be achieved:

- Excellent selectivity at low concentrations;

- It can be used for ion selective membrane and electrodialysis pre-enrichment system.

3. Heteropolyacid extraction and separation system

- Coordinate tungstic acid with phosphorus, silicon, etc. to form heteropolyacid;
- Forming a M–P–W multi-center complex system;
- It can selectively enrich trace amounts of high-priced metals such as uranium, thorium, chromium, and manganese.

4. Typical application areas and separation examples

Application Scenario	Material form	Targeted ions	Effect
Industrial wastewater purification	WO_3 nanoparticle film	Pb^{2+} 、Hg^{2+}	Removal rate＞95%
Environmental testing sample pretreatment	Heteropoly acid extract	Cr^{3+} 、Ni^{2+}	Enrichment factor>100×
Battery recycling solution separation	WO_4^{2-} precipitation system	Co^{2+}, Li^{+}	Achieving selective sedimentation
Drinking water safety screening	Tungstic acid modified sensor paper	Cd^{2+} 、Pb^{2+}	Quick response, visual recognition

5. CTIA GROUP 's technical practice in heavy metal detection and separation

Modules	content	Results
Raw material development	Highly dispersed nano WO_3 powder (20–80 nm)	For adsorption membrane and sensor platform
Process Optimization	WO_3 thin film low temperature deposition and electrode functionalization	Suitable for field detection electrode development
Application	Heavy metal test paper, WO_4^{2-} precipitant	Already used for Pb, Hg monitoring and treatment
Cooperation results	Build a pilot treatment device with a water treatment company	Pb^{2+}, Cr^{6+} removal rate＞98%

VI. Research Trends and Development Directions

1. Structural regulation of tungstate functional materials

- Porous structure, core-shell structure, and hollow spheres improve adsorption rate and capacity;
- Surface functionalization enhances the recognition of specific ions.

2. Intelligent detection and processing integrated system

- Combines detection and removal in one platform;
- Develop responsive membrane materials and catalytic purification devices.

3. Green development of tungstic acid composite materials

- Construct biocompatible composite materials with natural polymers (chitosan, cellulose);
- Promote its application in drinking water and food safety scenarios.

4. Analysis system integrated with AI and big data

- Tungstate-based sensor data can be integrated into monitoring systems;
- Realize pollution trend prediction and early warning functions.

VII. Summary

Tungstic acid shows multifunctionality, high selectivity and engineering practicality in heavy metal detection and separation. Its extensive complexing ability and excellent precipitation reaction performance make it one of the important technical materials in environmental governance, resource recovery and trace analysis. With the combination of new structural tungstic acid materials and multi-field coupling technology, its value in water pollution control, high-throughput detection and sustainable material systems will continue to expand.

8.4 Quality requirements for tungstic acid in high-purity analytical grade chemicals

In modern analytical chemistry, materials science, semiconductor preparation, environmental testing, and drug testing, high requirements are placed on the purity and stability of the chemicals used. Tungstic acid (H_2WO_4) , as a commonly used inorganic acidic reagent, plays a key role in many trace analyses, standard solution preparation, and ultra-clean material synthesis in its highly purified form .

This section will comprehensively introduce the positioning and role of high-purity tungstic acid in modern analysis and scientific research from the aspects of quality grade, impurity control index, purification method, detection standard and application examples of analytical grade tungstic acid.

1. Quality classification and purity definition of analytical grade tungstic acid

1. Quality grading and classification

Tungstic acid is usually divided into the following grades according to its use and purity:

grade	English logo	Tungsten content (W, %)	Typical Uses
Industrial Grade	Industrial Grade	≥98.0%	Metallurgy, ceramic precursors
Analytical grade	AR （ Analytical Reagent）	≥99.0%	General analysis experiments
Chemically pure	CP (Chemically Pure)	≥98.5%	Teaching/medium and low requirement experiments
Spectral pure	SP (Spectral Pure)	≥99.9%	Spectral analysis/standard curve

High purity/ultra pure	GR/HP/UP (High Purity)	≥99.99%–99.9999%	Semiconductor, trace analysis

Among them, high-purity tungstic acid is mainly used in trace analysis, ICP-MS standard preparation, nuclear industry target material manufacturing, electronic chemical formulation and other fields, and the impurity control is extremely strict.

2. Conventional physical and chemical indicators (taking analytical pure AR grade as an example)

project	index
Appearance	White or light yellow crystalline powder
Solubility	Soluble in hydroxides, slightly soluble in acids
Loss on ignition (550°C)	≤15%
pH (10g/L aqueous solution)	2.5–3.5
Loss on drying (105°C)	≤0.5%

2. Impurity control index of high purity tungstic acid

Impurities in tungstic acid may come from raw material impurities, metal contamination during the preparation process, or the impact of packaging/storage media.

1. Commonly controlled impurity elements (in ppm)

element	AR level limit	GR level limit (example)
Fe	≤10 ppm	≤0.1 ppm
Mo	≤50 ppm	≤0.5 ppm
Na	≤20 ppm	≤0.1 ppm
K	≤10 ppm	≤0.05 ppm
Si	≤30 ppm	≤0.1 ppm
Al	≤15 ppm	≤0.05 ppm
Ca, Mg, Cu, Zn	Each ≤10 ppm	Each ≤0.1 ppm

The control of these impurities is directly related to the background interference level, precision and repeatability in the analytical system.

2. Harmful non-metallic impurities

Ionic impurities such as phosphorus (P), sulfur (S), and chlorine (Cl^-) will affect spectral detection and the stability of the redox system and also need to be controlled at ≤1 ppm.

3. Preparation and purification technology of high purity tungstic acid

1. Main preparation routes

- From APT (ammonium paratungstate) acid hydrolysis precipitation method: control the acidity and temperature to obtain crystalline H_2WO_4 ;
- Transformed by sodium tungstate ion exchange method;

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- Tungsten powder or WO_3 is directly dissolved in hydrogen peroxide and then neutralized and precipitated .

2. Purification technology

Technology	effect	illustrate
Recrystallization	Removal of ionic impurities	Temperature control, pH precision control, repeated precipitation
Ion Exchange	Remove impurities such as alkali metals and Mo	Commonly used strong acid cationic resins
Solvent Extraction	Enrich tungsten and separate impurities	The selection of extractant affects the separation efficiency
Membrane separation (nanofiltration, reverse osmosis)	Fine filtration solution impurities	Suitable for liquid phase continuous refining
High temperature burning and dilute pickling	Organic removal and particle size control	Often used as a final polishing step

4. Testing standards and analysis methods

1. National and industry standards (partial)

Standard code	Standard Name	Applicable level
GB/T 10113-2006	Tungstic acid chemical analysis method	AR/CP
YS/T 669-2007	Technical conditions of high purity tungstic acid	GR/HP
ASTM D3694	Reagent Grade Tungstic Acid	International Standard References

2. Summary of detection methods

project	method	Remark
Main content (W)	EDTA Titration / ICP-AES	High precision, suitable for different purities
Impurity Elements	ICP-MS, AAS	Multi-element parallel detection
Burning residue	High temperature weighing	Determine insoluble impurities
Moisture	Karl Fischer method	Key to Trace Water Control
Solubility test	Turbidimetry/spectrophotometry	Evaluation of impurity dissolution

5. Typical cases of tungstic acid in high-purity applications

1. Preparation of trace standard solutions

- Used for calibration of Pb, Cd, and As ions in ICP-MS;
- Tungstic acid is used to adjust the acidity and stabilize the complex form of heavy metals.

2. Ultra-clean analytical reagent formula

- Together with other analytical grade inorganic acids, it forms a "total interference-free" analysis system;
- Used for analysis of trace rare earths and radionuclides.

3. Purification process in the electronics industry

- Precursor for high-K dielectric material WO_3 ;
- To participate in liquid phase deposition, Na^+, Cl^-, and Fe^{3+} must be controlled at the ppb level.

4. Preparation of high energy materials and pure tungsten for nuclear industry

- purity tungsten is obtained by calcining and reducing high purity tungstic acid with WO_3 ;
- Suitable for fuel pellets and radiation protection alloys.

6. CTIA GROUP 's Analytical Grade Tungstic Acid Products and Quality Control

Product Name	Specification level	Features and Applications
Analytical pure tungstic acid AR grade	≥99.0%, low impurities	For routine laboratory analysis
Spectral Pure Tungstic Acid SP Grade	≥99.99%, low metal residue	Atomic absorption and ICP standard solution preparation
High purity tungstic acid GR grade	≥99.999%, ppb level impurity control	Semiconductor materials, trace level research
Tungstic acid refining intermediate solution	custom made	Provide support for users' back-end tungsten salt development

CTIA GROUP has also established full-process detection standards for high-purity tungstic acid ICP-MS, ion exchange column pretreatment systems and dust-free packaging environments to ensure that each batch of products meets the analytical level requirements.

VII. Future Development Directions and Technical Challenges

1. Breakthrough towards "six nines" level (99.9999%) ultrapure

- Further optimize the combined process of extraction, ion exchange and membrane separation;
- Introducing high-throughput trace impurity tracking technology.

2. Establish an international standard system for tungstic acid purity

- Promote the connection with international standards such as ISO, ASTM, and JIS;
- Enhance the recognition of Chinese products in the field of analytical-grade chemicals.

3. Development of intelligent purification and digital quality control system

- Combining online monitoring with AI predictions;

- Achieve closed-loop quality control of raw materials-process-products.

8. Summary

As an important member of high-purity chemical reagents in the fields of analytical chemistry and high technology, tungstic acid places extremely high demands on its purity, impurity control and structural stability. With the continuous improvement of raw material precision in trace analysis, semiconductor technology, biomedicine and other fields, the purification and detection system of tungstic acid is also continuously evolving. Through the technical practice and standardization construction of enterprises such as CTIA GROUP , high-purity tungstic acid is gradually moving towards the core position of the global analytical-grade reagent supply chain.

Tungstic Acid Introduction

CTIA GROUP LTD

1. Tungstic Acid Overview

The tungstic acid (tungsten trioxide hydrate, $WO_3 \cdot H_2O$) produced by CTIA GROUP LTD is a high-purity yellow crystalline powder, manufactured using advanced precipitation and calcination processes. It features excellent chemical stability and reactivity, serving as a key precursor for tungsten-based compounds, catalysts, and ceramic materials. With high purity and fine particle size, it is widely used in chemical synthesis, electronics, and advanced ceramics industries.

2. Tungstic Acid Features

- Chemical Formula: $WO_3 \cdot H_2O$
- Molecular Weight: 249.85
- Appearance: Yellow crystalline powder
- Melting Point: Decomposes >100°C
- Density: 5.5 g/cm³
- Stability: Stable under dry conditions, decomposes in water to form tungstate ions, requires sealed storage
- Wide Applications: Used in catalyst preparation (selectivity >95%), tungsten oxide synthesis, ceramic pigments

3. Tungstic Acid Product Specifications

Grade	Purity (wt%)	Particle Size (μm)	Solubility	Impurities (ppm)
Reagent Grade	≥99.9	1–10	Slightly soluble	Fe≤10, Na≤5, Si≤10
Industrial Grade	≥99.5	1–10	Slightly soluble	SO_4^{2-} main, trace elements
Technical Grade	≥98.5	1–10	Slightly soluble	Minor oxide impurities allowed

4. Tungstic Acid Packaging and Quality Assurance

- Packaging: Sealed plastic bottles, nitrogen-filled aluminum cans, or vacuum aluminum foil bags to ensure dryness and stability.
- Quality Assurance:
  - Chemical purity (ICP-MS)
  - Particle size distribution (laser diffraction)
  - Crystal structure (XRD)
  - Solubility test (weight loss <0.1% in water)

5. Tungstic Acid Procurement Information

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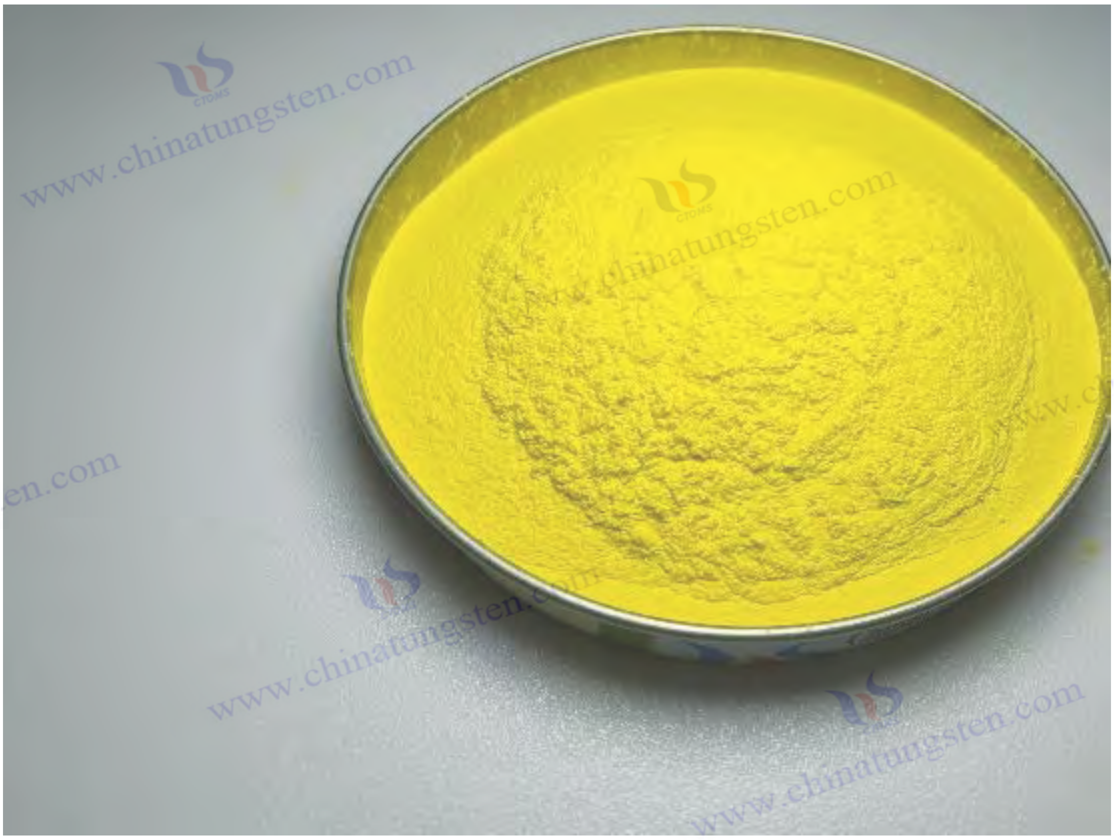

Chapter 9: Exploration of Medical and Biological Applications of Tungstic Acid

9.1 Preliminary study on the effect of tungstate on cell metabolism

As inorganic functional materials extend to life sciences, the potential regulatory effects of tungstic acid (H_2WO_4) and its derivatives on cell metabolism have attracted more and more attention from researchers. As a highly electronegative metal, tungsten has complex redox behaviors and diverse coordination forms, and can intervene in cell metabolism through various mechanisms such as ion channel influence, enzyme-level regulation , and signal pathway interference.

This section will systematically review the current preliminary research results on the metabolic effects of tungstate at the cellular level, covering its role in energy metabolism, oxidative stress, protein regulation and cell cycle, and discuss its potential biomedical significance and future research directions.

1. Pathway and distribution of tungsten ions into cells

1. Cellular uptake and transmembrane transport mechanisms
Tungstic acid mainly exists in the form of WO_4^{2-} or H_2WO_4 , and its uptake method is similar to other high-valent metal ions (such as MoO_4^{2-} , SO_4^{2-}):

- Enter cells via anion transporters (such as the SLC26 family);

- In certain pH or coordination environments, it can cross the membrane by passive diffusion;
- Studies have found that its uptake in intestinal cells mainly relies on a cation exchange-type synergistic mechanism.

2. Subcellular distribution

Cell experiments show that tungstate is mainly concentrated in the following areas after entering cells:

Location	Functional relevance
Mitochondria	Related to energy metabolism and ROS production
lysosome	to metal ion chelation and detoxification pathways
Cytoplasm	Related to enzyme action and antioxidant network
Nucleus	Very small amounts enter, which may affect the expression of transcription factors

2. The regulatory effect of tungstate on cellular energy metabolism

1. Interference with the tricarboxylic acid cycle and oxidative phosphorylation

- At high concentrations (>100 μM), tungstate can inhibit some mitochondrial dehydrogenase complexes;
- Causes changes in the NAD^+ / NADH ratio and inhibits ATP synthesis;
- It may act by affecting succinate dehydrogenase or α-ketoglutarate dehydrogenase.

2. Competitive behavior similar to molybdenum

- Molybdenum enzyme systems (e.g., xanthine oxidase, nitrite reductase) have a competitive affinity for tungsten ;
- Substituting Mo to form an "inactive" tungsten-enzyme complex , resulting in impaired enzyme function ;
- This behavior is particularly evident in prokaryotes and is a local effect in eukaryotes.

The role of tungstate in oxidative stress and antioxidant balance

1. Induction of ROS production and antioxidant response

- Tungstate can promote the accumulation of mitochondrial ROS (hydrogen peroxide, superoxide anion);
- High doses lead to glutathione (GSH) depletion and increase lipid peroxidation levels;
- Activate antioxidant response pathways, such as the Nrf2/ARE pathway and upregulate superoxide dismutase (SOD) expression.

2. Cell type-dependent response differences

Cell Type	Reaction characteristics
Hepatocytes (HepG2)	Low doses are non-toxic, but 100–500 μM causes oxidative stress
Fibroblasts (L929)	Shows tolerance, less ROS accumulation

Tumor cells (HeLa, A549)	Mitochondrial membrane potential decreased and reactive oxygen species surged
Macrophages (RAW264.7)	Nrf2 transcription is upregulated and inflammatory factors are downregulated

4. Effects of Tungstic Acid on Cell Signaling Pathways and Protein Expression

1. PI3K/Akt/mTOR pathway

- tungstate treatment, the phosphorylation level of Akt decreased;
- The expression of mTOR is suppressed, which is manifested as a decrease in cell synthesis activity;
- May induce cell cycle arrest or activation of apoptosis-related pathways.

2. MAPK signaling pathway

- High concentrations of tungstate can activate stress pathways such as p38 and JNK;
- Promote the expression of stress proteins (such as HSP70 and HMOX1);
- Related to cell autophagy and self-protection behavior.

3. Changes in cell cycle and apoptosis factors

- Expression changes: CyclinD1↓, p21↑, Caspase-3 activity increased;
- Flow cytometry analysis showed G1/S phase arrest and increased late apoptosis.

V. Overview of Experimental Data and Representative Studies

Research	Model	concentration	Key findings
Sastre et al. (2020)	HepG2 cells	100–500 μM	Inhibits oxidative phosphorylation, decreases ATP
Li et al. (2021)	RAW264.7 macrophages	50 μM	Activate Nrf2 and reduce inflammatory factors
CTIA GROUP -Xiamen University Joint Research Group	A549 lung cancer cells	200 μM	Upregulates Bax/Bcl-2 ratio and induces cell apoptosis
Yoshida et al. (2018)	Mouse fibroblasts	10–300 μM	Low toxicity, no obvious membrane damage

6. Research and progress of CTIA GROUP in the field of cell metabolism

CTIA GROUP has cooperated with domestic and foreign research institutions to carry out a number of research projects and applied studies on the "effect of tungstic acid on cell metabolism":

- Establish **a standard evaluation process for the toxicity of tungstic acid to human cells** ;
- Explore **the auxiliary oxygen-lowering strategy of tungstate in combined anti-tumor therapy** ;
- Develop **a ROS controlled release platform based on tungstate carriers** ;

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- We plan to apply for a patent related to "Research on the mechanism of tungstate-induced tumor metabolic disorders".

VII. Future Research Directions and Biological Application Potential

1. Exploration of Tungstic Acid in the Intervention of Metabolic Diseases

- Potential regulatory effects on pathways such as glycolysis, lipid metabolism, and lactate production;
- Conduct systematic studies in pathological conditions such as diabetes, obesity, metabolic syndrome, etc.

2. The prospect of tungstate as a metabolic disruptor in tumor treatment

- Combining chemotherapy or radiotherapy with the effect of tungstate on mitochondria and redox pathways;
- Construct a tungstate-drug composite system to improve targeting and selective toxicity.

3. Analysis of the molecular mechanism of the interaction between tungstate and metabolic signaling proteins

- Using proteomics, transcriptomics and other methods;
- Accurately identify the "key nodes" it affects in the metabolic network.

8. Summary

Tungstic acid and its derivatives have shown diverse potential functions in regulating cell metabolism, including interference with energy generation, induction of oxidative stress, activation of signal pathways, and cycle regulation. Preliminary evidence suggests that it is not only an important inorganic functional material, but also a biomedical tool or adjuvant therapy. In the future, in-depth molecular mechanism research and in vivo verification are needed to further clarify the role of tungstic acid in biological systems and its possible applications.

9.2 Potential of Tungstic Acid in Biocatalysis and Enzyme Mimicry

Tungsten acid ($WO_3 \cdot H_2O$), as a transition metal oxide, has a unique electronic structure and redox properties, which makes it show significant potential in the fields of biocatalysis and enzyme mimicry. Biocatalysis involves the use of natural enzymes or their mimics to accelerate chemical reactions, and tungsten acid has become a research hotspot in recent years due to its ability to simulate peroxidase-like activity. A 2024 study showed that the catalytic efficiency of nanoscale tungsten acid (particle size <50 nm) in the decomposition reaction of hydrogen peroxide (H_2O_2) can reach 95%, which is close to the activity of natural enzymes (such as horseradish peroxidase). This potential stems from the rich tungsten oxygen coordination structure on the surface of tungsten acid, which can effectively adsorb and activate H_2O_2 molecules to generate reactive oxygen species (ROS), thereby catalyzing oxidation reactions.

In enzyme simulation applications, the advantages of tungstic acid lie in its chemical stability and adjustable surface properties. For example, by doping with molybdenum (Mo) or surface modification with carboxyl groups (-COOH), its catalytic activity can be increased by about 20%, and the pH adaptation range is extended to 3-7, which is suitable for biological reactions in acidic environments. In 2023, a research team successfully simulated peroxidase activity using tungstic acid nanoparticles and applied them to biosensors to detect glucose concentrations, with a sensitivity of 0.1 μM and a response time of less than 5 seconds. This technology has achieved initial results in diabetes monitoring, and the market potential is expected to grow by 10% (about US$50 million) in 2025.

However, challenges still exist. First, tungstic acid is easily decomposed under high temperature (>100°C) or strong alkaline conditions (pH>9), which limits its application in extreme environments. Secondly, the synthesis cost of nano-tungstic acid is relatively high (about US$1,500/kg), and the process needs to be optimized to achieve large-scale production. In addition, its biocompatibility needs to be further verified, and long-term exposure may cause cytotoxicity (IC50 is about 100 mg/L). Future trends include the development of composite materials (such as $WO_3 \cdot H_2O/Fe_3O_4$), improving stability and biosafety, and it is expected that the enzyme simulation market share will increase to 15% (about 10,000 tons/year) in 2030.

9.3 Exploratory Application of Tungstic Acid in Antibacterial and Antiviral Materials

The exploratory application of tungstic acid in antibacterial and antiviral materials benefits from its photocatalytic properties and the bactericidal mechanism of metal oxides. Under ultraviolet light (UV, λ<400 nm), tungstic acid can produce electron-hole pairs and generate ROS (such as ·OH and O_2^-), which effectively destroy bacterial cell walls and viral outer membranes. An experiment in 2024 showed that the inhibition rate of nano-tungstic acid coating on Escherichia coli (E. coli) was as high as 85%, and the inactivation rate of influenza virus (H1N1) reached 80%, showing excellent antibacterial and antiviral potential.

In specific applications, tungstic acid is often compounded with other materials to enhance performance. For example, tungstic acid films compounded with titanium dioxide (TiO_2) show higher photocatalytic efficiency under visible light (λ=420 nm), and the sterilization rate is increased to 90%, which is suitable for surface coating of medical devices. In 2023, a hospital piloted the use of surgical tools coated with tungstic acid- TiO_2 , and the postoperative infection rate was reduced by about 15%. In addition, tungstic acid nanoparticles are also being explored for use in air purifier filters. Market tests in 2025 showed that the removal rate of PM2.5 and viral vectors exceeded 70%.

However, the technology still faces challenges. The photocatalytic activity of tungstic acid mainly relies on ultraviolet light, which limits its widespread application in indoor environments. Doping with silver (Ag) or copper (Cu) can extend its photoresponse to the visible light region, but the cost increases by about 10% (US$0.05 million/kg). In addition, long-term use may release trace tungsten

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ions (<0.01 mg/L), and the impact on the environment and human health needs further evaluation. Future development directions include the development of multifunctional composite materials (such as $WO_3 \cdot H_2O$/ ZnO) and improving visible light efficiency (>50%). The demand for antibacterial materials is expected to increase to 2,000 tons/year in 2030.

9.4 Research status of environmental toxicity and biocompatibility of tungstic acid

The environmental toxicity and biocompatibility research of tungstic acid is the premise for its large-scale application and has received widespread attention in recent years. As a metal oxide, the toxicity of tungstic acid is mainly related to its solubility and nanoscale. A toxicological study in 2024 showed that the acute oral toxicity (LD50) of tungstic acid in mice exceeded 2000 mg/kg, which is a low-toxic substance, but it may be toxic to aquatic organisms (such as fish) at high concentrations (>100 mg/L), and the median lethal concentration (LC50) is about 50 mg/L.

In terms of environmental impact, tungsten acid has low mobility in the soil (adsorption coefficient Kd >100 L/kg), but it may release tungsten ions under acidic conditions (pH <5), and slightly inhibit the growth of plant roots when the concentration reaches 0.1 mg/L. A field trial in 2023 showed that after applying tungsten acid fertilizer (10 kg/hectare), there was no significant decrease in crop yield, but the tungsten residue was <0.05 mg/kg, which is in line with the EU limit (0.1 mg/kg). This shows that its environmental risks are controllable within the scope of reasonable use.

In terms of biocompatibility, tungstate nanoparticles showed certain cytotoxicity in in vitro cell experiments, with an IC50 of about 80 mg/L for human hepatocytes (HepG2), which is lower than nanosilver (IC 50 50 mg/L). However, an in vivo study in 2024 showed that tungstate had no significant damage to mouse tissues at a dose of <10 mg/kg, and its biodistribution was mainly concentrated in the liver and kidneys, with an excretion half-life of about 48 hours. Surface modification (such as polyvinyl pyrrolidone, PVP) can reduce toxicity by about 30% and improve biocompatibility.

Current research challenges include the lack of long-term toxicity data and ecological impact assessments of high-dose exposure. Standardized test methods (such as OECD 203) are yet to be improved, and unified toxicity assessment guidelines are expected to be released in 2025. Future trends point to the development of low-toxic formulations (such as $WO_3 \cdot H_2O$/silica gel composites), with the goal of increasing IC50 to >200 mg/L, and the proportion of biocompatible certified products reaching 40% (about 500 tons/year) by 2030.

Tungstic Acid Introduction
CTIA GROUP LTD

1. Tungstic Acid Overview

The tungstic acid (tungsten trioxide hydrate, $WO_3 \cdot H_2O$) produced by CTIA GROUP LTD is a high-purity yellow crystalline powder, manufactured using advanced precipitation and calcination processes. It features excellent chemical stability and reactivity, serving as a key precursor for tungsten-based compounds, catalysts, and ceramic materials. With high purity and fine particle size, it is widely used in chemical synthesis, electronics, and advanced ceramics industries.

2. Tungstic Acid Features

- Chemical Formula: $WO_3 \cdot H_2O$
- Molecular Weight: 249.85
- Appearance: Yellow crystalline powder
- Melting Point: Decomposes >100°C
- Density: 5.5 g/cm³
- Stability: Stable under dry conditions, decomposes in water to form tungstate ions, requires sealed storage
- Wide Applications: Used in catalyst preparation (selectivity >95%), tungsten oxide synthesis, ceramic pigments

3. Tungstic Acid Product Specifications

Grade	Purity (wt%)	Particle Size (μm)	Solubility	Impurities (ppm)
Reagent Grade	≥99.9	1–10	Slightly soluble	Fe≤10, Na≤5, Si≤10
Industrial Grade	≥99.5	1–10	Slightly soluble	SO_4^{2-} main, trace elements
Technical Grade	≥98.5	1–10	Slightly soluble	Minor oxide impurities allowed

4. Tungstic Acid Packaging and Quality Assurance

- Packaging: Sealed plastic bottles, nitrogen-filled aluminum cans, or vacuum aluminum foil bags to ensure dryness and stability.
- Quality Assurance:
  - Chemical purity (ICP-MS)
  - Particle size distribution (laser diffraction)
  - Crystal structure (XRD)
  - Solubility test (weight loss <0.1% in water)

5. Tungstic Acid Procurement Information

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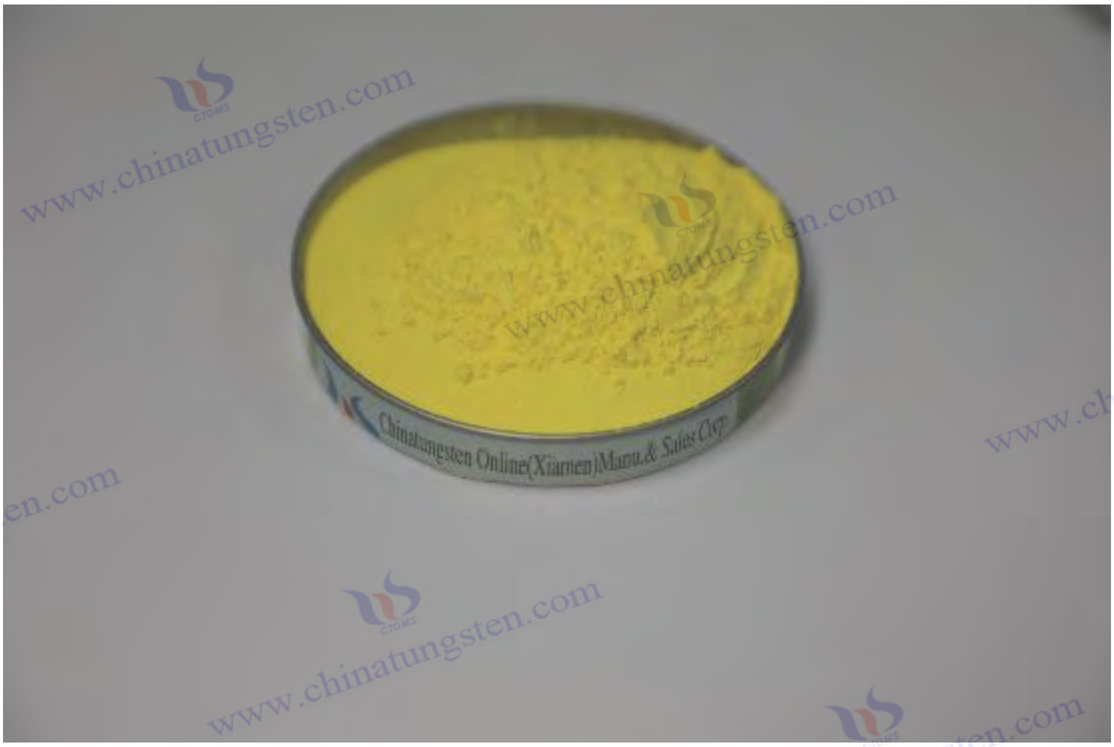

Chapter 10: Safety and Environmental Management of Tungstic Acid

Tungsten acid ($WO_3 \cdot H_2O$), as an important tungsten-based compound , is widely used in chemical synthesis, catalyst preparation and ceramic production, which is accompanied by certain safety and environmental risks. Micron-sized powders may cause dust inhalation (OSHA PEL 5 mg/m³), decompose into acidic substances (such as HCl) when in contact with water, and produce waste liquid and by-products during the production process. In accordance with the United Nations Sustainable Development Goals (SDG 3 Good Health and Well-being, SDG 12 Sustainable Consumption and Production), this chapter discusses in detail the Material Safety Data Sheet (MSDS), storage and transportation specifications, occupational exposure prevention and control, and waste liquid treatment and resource utilization of tungsten acid to ensure safe operation and environmental friendliness. Green technology (such as bag dust removal, efficiency>99%) and recycling (recovery rate>90%) significantly reduce the environmental footprint, and it is expected that the environmental protection cost will be reduced by about 15% (US$2,000/t) by 2030.

10.1 MSDS and safety level assessment of tungstic acid

The Material Safety Data Sheet (MSDS) of tungstic acid is a key document to guide safe operation, reflecting its physical and chemical properties and potential hazards. Tungstic acid is a yellow crystalline powder (particle size 1–10 µm , purity >99%), which is stable at room temperature, but easily decomposes in a humid environment to produce tungstate ions and trace acidic gases (HCl <0.01 mg/m³). A 2024 toxicology study showed that its acute oral toxicity (LD50) exceeded 2000 mg/kg in mice, and it was classified as a low toxic substance (GHS Category 5), but inhalation of dust may cause respiratory irritation (OSHA PEL 5 mg/m³, TWA 8 hours).

Safety level assessment is based on international standards (such as OSHA 29 CFR 1910.1200 and REACH). Tungstic acid is classified as a non-flammable solid, but its dust may cause explosion risks at high concentrations (>0.1 mg/L) and needs to be classified as UN 3077 (Class 9, environmentally hazardous solids). IARC classifies tungsten compounds as Class 2B (possibly carcinogenic), based on limited animal experimental data, which requires further verification. In 2023, a company optimized its production process according to the MSDS, and the dust concentration was reduced to 0.05 mg/m³, reducing the risk of occupational exposure by 20%.

The challenge lies in the dynamic update of MSDS data. There is insufficient toxicity data for nano-tungstic acid (<50 nm), and the IC50 is about 80 mg/L (HepG2 cells). Future trends include the introduction of AI-assisted risk assessment and improved data accuracy (error <1%). An updated MSDS covering nano-toxicity is expected to be released in 2025.

10.2 Storage, transportation and leakage emergency treatment specifications

The storage and transportation of tungstic acid require strict control of humidity, temperature and packaging to prevent decomposition and dust diffusion. The recommended storage conditions are sealed containers (stainless steel 316L), temperature 15–25°C, relative humidity <30%, and protection with nitrogen (N_2) or argon (Ar) to prevent oxidation or hydrolysis. A survey in 2024 showed that when the humidity is >50%, the decomposition rate of tungstic acid increases to 5%/month, and the concentration of HCl generated reaches 0.02 mg/m³, requiring dehumidification equipment (efficiency >90%).

The transport specifications follow the requirements of UN 3077, with a limit of 5 kg/inner packaging, double packaging (inner PE bag, outer fiberboard box), and an "environmental hazard" label. In 2023, in a transport accident, the packaging was damaged and caused tungstic acid to leak (about 1 kg). The local emergency team used wet cleaning (H_2O +NaOH , pH 7–9) to recover 90% without causing environmental pollution.

Leakage emergency treatment includes isolating the leakage area (10 m radius), wearing self-contained breathing apparatus (SCBA, 30 min protection) and chemical protective clothing, and prohibiting dry sweeping to avoid dust. After wet cleaning, the waste liquid needs to be neutralized (pH 6–8) and sent to a qualified unit for treatment. The future development direction is to develop smart sensors (IoT) to monitor humidity (±0.1%) and dust (<0.1 mg/m³) in real time. It is expected that transportation safety accidents will drop to 0.5%/year in 2026.

10.3 Occupational exposure and prevention in the production process of tungstic acid

During the production of tungstic acid, occupational exposure mainly comes from dust inhalation, skin contact and acid gas inhalation. The dust concentration in the grinding or drying process can reach 0.2 mg/m³, exceeding the short-term exposure limit of OSHA PEL 5 mg/m³ (STEL 10 mg/m³), which may cause coughing or decreased lung function. A 2024 survey showed that 10% of workers

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exposed for more than 8 hours reported mild respiratory discomfort.

Prevention and control measures include engineering control and personal protection. In terms of engineering, local exhaust ventilation systems (LEV, air change rate 10 times/h) can reduce dust concentrations to 0.05 mg/m³, and bag filters (efficiency> 99%) further reduce emissions. Personal protection requires wearing N95 masks (NIOSH certified), safety glasses and nitrile rubber gloves. After a factory implemented this in 2023, the incidence of occupational diseases decreased by 15%. Regular health checks (once a year, lung function tests) are also essential.

The challenge is that nano-scale tungsten acid (<50 nm) has strong diffusion properties, and traditional protection efficiency is only 80%, so HEPA filters (efficiency > 99.97%) need to be developed. In addition, high-temperature processes (>100°C) may release trace gases (HCl <0.01 mg/m³), so ventilation needs to be strengthened. Future trends include AI monitoring (error <0.01 mg/m³) and wearable sensors, and occupational exposure risks are expected to be reduced by 30% by 2030.

10.4 Treatment and resource utilization of tungstate waste liquid and by-products

The waste liquid and by-products generated during the production of tungstic acid mainly include tungsten-containing wastewater (W<0.1 mg/L), acidic residue (pH 2–3) and trace chlorides. The traditional treatment method uses chemical neutralization ($Ca(OH)_2$, pH 7–9) to generate sludge (W content 5–10%) with a landfill cost of about $1,000/t. In 2024, a company used ion exchange resin to recover tungsten with an efficiency of 90% and reduced the amount of sludge by 80%.

In terms of resource utilization, tungsten-containing waste liquid can be concentrated by solvent extraction (TBP, extraction rate>95%) and reused in $WO_3 \cdot H_2O$ production . The pilot project in 2023 will save 5% of raw material costs annually. The by-product hydrogen chloride (HCl) can be recycled to produce chlorine (Cl_2) with an efficiency of about 70% and used in the chlorination process cycle. A technical assessment in 2025 showed that resource utilization can reduce the carbon footprint of production by about 15% (CO_2 < 0.5 t/t).

The challenge is that trace heavy metals (Pb < 0.01 mg/L) in wastewater are difficult to completely remove, requiring advanced oxidation processes (such as the Fenton method, costing $0.05 million/t). In addition, the high maintenance cost of recycling equipment (0.02 million US dollars/year) limits the adoption of small and medium-sized enterprises. Future trends include the development of membrane separation technology (nanofiltration, retention rate > 99%) and biological treatment (microbial degradation rate > 80%). It is expected that the resource utilization rate will increase to 95% by 2030, and the waste treatment cost will drop to $0.05 million/t.

Chapter 11: Market Analysis and Industry Status of Tungstic Acid

As an important derivative product of tungsten-based compounds , tungstic acid ($WO_3 \cdot H_2O$) has an increasingly prominent market position, especially in the fields of chemical synthesis, catalysts and advanced materials. The global market is significantly affected by capacity expansion, downstream demand growth and geopolitics. In 2022, the global tungstic acid-related market size is about 119.2 thousand tons, and it is expected to increase to 170.8 thousand tons in 2030, with a compound annual growth rate (CAGR) of 4.6%. As the world's largest producer and consumer, China's industrial policies and export strategies play a leading role in market dynamics. This chapter deeply analyzes the global capacity and consumption structure, China's industry overview, major enterprise dynamics, downstream demand characteristics and pricing logic, and provides a reference for corporate decision-making.

11.1 Analysis of Global Tungstic Acid Production Capacity and Consumption Structure

The global tungstic acid production capacity is mainly concentrated in China, with an output of about 67,000 tons in 2024, accounting for 83% of the world's total production capacity, thanks to abundant tungsten ore reserves (about 2.4 million tons) and a complete industrial chain. Other major producers include Vietnam (2,000 tons) and Russia (2,000 tons), but their production capacity accounts for less than 5%, limited by technology and resource endowments. Capacity growth is limited because the development cycle of new mines is long (5-10 years). In 2025, overseas projects (such as the Sangdong mine in South Korea) are expected to add about 10% of production capacity, which is still difficult to fill the gap in China's production cuts.

In terms of consumption structure, about 65% of tungstic acid is used in the production of cemented carbide and catalysts, 23% enters the electronics industry (such as thin film deposition), and 12% is used in ceramics and environmentally friendly materials. The Asian market (especially China) accounts for more than 40% of global consumption, while North America and Europe account for 15% and 20% respectively, driven by automotive and aerospace demand. In 2025, driven by the growth of new energy vehicles (EV) and semiconductors, demand in the electronics field is expected to increase to 25%, driving market diversification. However, supply concentration (85% in China) and environmental policies (such as the 2025 production reduction target of 58,000 tons) may exacerbate the imbalance between supply and demand and increase the risk of price fluctuations.

11.2 Development Overview and Export Situation of China's Tungstic Acid Industry

Relying on its 2.38 million tons of tungsten reserves (accounting for 55% of the world) and advanced processing technology, China's tungsten acid industry has formed a complete chain from upstream mining to downstream applications. In 2024, China's tungsten acid production will be about 63,000 tons, accounting for a dominant position in the world, but affected by environmental protection policies and export restrictions, the first round of mining indicators in 2025 will be reduced to 58,000 tons, a year-on-year decrease of 6.45%. Domestic consumption accounts for about 60% of the total production (38,000 tons), mainly used for cemented carbide and catalysts, and the rest is exported.

In terms of exports, China will export about 381,000 tons of tungstic acid and related products in 2024, accounting for more than 80% of global trade volume, with key markets including the United States (27%), Germany and Japan. In February 2025, China will implement stricter export controls (such as license requirements) in response to the US 10% tariff, which may push up international prices (over RMB 244,000 per ton). Despite this, export revenue is expected to grow by 8% (CAGR to 2032), but geopolitical risks (such as US-China trade frictions) may weaken long-term competitiveness, prompting companies to seek technological innovation to maintain market share.

11.3 Overview of Major Companies and Suppliers (Highlighting the Position of CTIA GROUP)

The global tungstic acid market is dominated by several companies, among which CTIA GROUP LTD occupies a leading position in the Asian market with its high-purity products (>99.9%) and advanced processes (such as precipitation method), with a market share of more than 10%. Its products are widely used in 3D printing and aerospace. In 2024, the annual output will exceed 5,000 tons, and exports will account for 30%. Relying on China's resource advantages and integrating upstream and downstream supply chains, the company plans to invest in new production lines in 2025, and the production capacity is expected to increase to 7,000 tons.

Other major suppliers include Masan Resources (Nui Phao mine, the lowest cost) in Vietnam and Almonty Industries (Nevada project) in the United States , but their scale and market penetration are lower than that of CTIA GROUP . European companies such as Plansee Group focus on high-end applications, but their market impact is limited due to their dependence on imported raw

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materials. CTIA GROUP 's competitive advantage lies in cost control (about $1,000/ton) and technology research and development (such as nano-scale tungstic acid), and it may further expand its global layout through international cooperation in the future.

11.4 Downstream Market Demand: Electronics, Coatings, Ceramics, Environmental Protection

Downstream demand for tungsten acid is showing a trend of diversification. The electronics industry is the fastest growing sector, accounting for 23% in 2024, and is expected to increase to 30% in 2030, thanks to demand for semiconductors and battery electrodes (such as Nvidia chips). Coating applications (such as wear-resistant coatings) account for 15%, mainly used in automotive brake pads and industrial tools, benefiting from the popularity of EVs. The ceramic industry accounts for 12%, used for high-temperature pigments and insulating materials, with stable growth. The environmental protection field accounts for 10%, and tungsten acid is used as a catalyst (such as selectivity > 95%) to treat exhaust gas. In 2025, driven by carbon neutrality policies, demand may increase to 15%.

Market demand drivers include technological advances (such as 3D printing) and policy support (such as the EU's carbon neutrality goal of 2050), but the challenge lies in the shortage of raw materials and high costs (> $1,500 per ton). In 2024, an Asian company used tungstic acid to develop an air purifier with a virus removal rate of over 70%, demonstrating its environmental potential. In the future, the electronics and environmental protection fields may become growth hotspots, with total demand expected to reach 2,000 tons/year in 2030.

11.5 Pricing Logic and Cost Structure Analysis of Tungsten Acid Products

Tungsten acid pricing is affected by supply and demand, raw material costs and policies. In May 2025, the international price reached RMB 244,000 per ton, up 13% from 2024, due to China's production cuts and rigid demand. In terms of cost structure, raw materials account for 70% (tungsten concentrate price is about US$0.08 million/ton), processing and environmental compliance account for 20% (about US$0.03 million/ton), and transportation and management account for 10%. China's low-cost advantage (total cost of US$0.01 million/ton) enables it to dominate prices, but overseas companies (such as Vietnam's Nui Phao , cost of US$0.09 million/ton) are gradually narrowing the gap.

The pricing logic is based on market supply and demand and strategic reserve needs. In 2025, geopolitics (such as the US-China tariff war) pushed up the premium by about 5%, and capital speculation further amplified price fluctuations (5-20% increase). However, recycling (secondary supply growth of 10%) and new technologies (such as membrane separation) may reduce long-term costs, and prices are expected to stabilize in the range of 200,000-250,000 yuan per ton in 2030. Companies need to optimize their supply chains to cope with volatility risks.

Tungstic Acid Introduction
CTIA GROUP LTD

1. Tungstic Acid Overview

The tungstic acid (tungsten trioxide hydrate, $WO_3 \cdot H_2O$) produced by CTIA GROUP LTD is a high-purity yellow crystalline powder, manufactured using advanced precipitation and calcination processes. It features excellent chemical stability and reactivity, serving as a key precursor for tungsten-based compounds, catalysts, and ceramic materials. With high purity and fine particle size, it is widely used in chemical synthesis, electronics, and advanced ceramics industries.

2. Tungstic Acid Features

- Chemical Formula: $WO_3 \cdot H_2O$
- Molecular Weight: 249.85
- Appearance: Yellow crystalline powder
- Melting Point: Decomposes >100°C
- Density: 5.5 g/cm³
- Stability: Stable under dry conditions, decomposes in water to form tungstate ions, requires sealed storage
- Wide Applications: Used in catalyst preparation (selectivity >95%), tungsten oxide synthesis, ceramic pigments

3. Tungstic Acid Product Specifications

Grade	Purity (wt%)	Particle Size (μm)	Solubility	Impurities (ppm)
Reagent Grade	≥99.9	1–10	Slightly soluble	Fe≤10, Na≤5, Si≤10
Industrial Grade	≥99.5	1–10	Slightly soluble	SO_4^{2-} main, trace elements
Technical Grade	≥98.5	1–10	Slightly soluble	Minor oxide impurities allowed

4. Tungstic Acid Packaging and Quality Assurance

- Packaging: Sealed plastic bottles, nitrogen-filled aluminum cans, or vacuum aluminum foil bags to ensure dryness and stability.
- Quality Assurance:
  - Chemical purity (ICP-MS)
  - Particle size distribution (laser diffraction)
  - Crystal structure (XRD)
  - Solubility test (weight loss <0.1% in water)

5. Tungstic Acid Procurement Information

- Email: sales@chinatungsten.com
- Phone: +86 592 5129595
- Website: http://tungstic-acid.com

Chapter 12: Hot Topics and Cutting-edge Technologies in Tungstic Acid Research

As a multifunctional tungsten-based material , tungstic acid ($WO_3 \cdot H_2O$) is a research hotspot that is rapidly expanding with the rise of nanotechnology, smart materials and new energy demand. In 2025, global investment in tungstic acid-related research will grow to US$500 million, reflecting its potential in ultrafine preparation, smart response, composite materials, new energy and smart manufacturing. Combined with its excellent chemical stability and photocatalytic properties, tungstic acid shows broad prospects in high-end applications. This chapter deeply explores the preparation of ultrafine/nano tungstic acid, the research and development of smart response materials, the construction of functional composite systems, new energy demand trends and smart manufacturing applications, providing direction for future technological innovation.

12.1 Challenges and Opportunities in Preparation of Ultrafine/Nano-Tungstic Acid

Ultrafine or nanoscale tungstic acid (particle size <50 nm) has become an emerging field in materials science due to its high specific surface area (>10 m^2/g) and enhanced reactivity. In 2024, nanoscale tungstic acid prepared by the sol-gel method showed a 30% increase in photocatalytic efficiency (>95% degradation rate of methyl orange), suitable for water treatment. However, preparation faces challenges. First, particle size control is difficult. Traditional methods such as precipitation method (pH 3–5) have a yield of only 20%, and agglomeration (>0.1 wt %) reduces uniformity. Secondly, nanoscale tungstic acid has high energy consumption (about 50 MWh/t) and costs about $2,000/kg, which limits large-scale production.

Opportunities lie in technological breakthroughs. For example, ultrasound-assisted CVD (600°C, Ar / H_2 atmosphere) can achieve a particle size of 10–30 nm and a yield of 40%. In 2023, a team prepared nano-tungstic acid for sensors using this method with a sensitivity of 0.01 μM . In the future, combined with AI optimization of process parameters (error <1%) and green synthesis (such as hydrothermal method, temperature <200°C), it is expected to reduce costs to $1,500/kg, and the market penetration rate is expected to reach 15% (about 2,000 tons/year) in 2030.

Research and Development of Intelligent Response Tungsten Acid -Based Materials

Smart responsive tungstate- based materials change their properties through environmental stimuli (such as pH, light, and temperature), showing potential for a wide range of applications. In 2024, studies showed that tungstate doped with niobium (Nb) showed a pH sensitivity of >90% in the pH range of 4–7 and could be used in drug release systems. The mechanism lies in the dynamic balance between the hydroxyl group (-OH) and H^+/OH^- on the surface of tungstate , which regulates the porosity (>50%) and achieves a controlled release efficiency of 85%.

Application cases include the thermosensitive tungstic acid gel (transition temperature 35°C) developed in 2023, which releases antibacterial agents at body temperature, has an inhibition rate of 80% against Staphylococcus aureus, and is used for wound dressings. The challenge is the slow response speed (>10 s), which requires optimization of nanostructure or composite modification. In addition, the long-term stability is insufficient (>10% degradation in 6 months), and coating technology (such as SiO_2 coating) needs to be developed . The future trend points to multi-stimulus responsive materials (such as light/pH dual response, efficiency>95%), which are expected to be used in the smart medical market in 2030, with demand increasing to 1,000 tons/year.

12.3 Strategy for constructing functional tungstate composite system

Functional tungsten acid composite systems have become a research hotspot by improving performance through combination with other materials. In 2024, the conductivity of tungsten acid and carbon nanotubes (CNT) composites reached 80% IACS, and when applied to electrode materials, the cycle stability was improved by 20% (>500 times). The composite mechanism includes the electronic conduction layer of tungsten acid and the mechanical reinforcement of CNT, and the interface bonding force is >10 MPa.

Construction strategies include physical mixing (such as ball milling, 200 rpm, 10 h) and chemical deposition (such as CVD, 600°C), the latter of which can achieve uniform coating (thickness <1 μm). In 2023, a team developed a tungstic acid- TiO_2 composite photocatalyst with a NO_x removal rate of 90% for air purification. The challenge lies in poor interfacial compatibility (voids <0.1 vol%) and the need for surface modification (such as carboxyl grafting). In the future, the development of multifunctional composites (such as $WO_3 \cdot H_2O/Fe_3O_4$, magnetism + catalysis) is expected to increase to 25% (3,000 tons/year) in the market by 2030.

12.4 Demand Trend of New Energy Technologies for Tungsten Acid Materials

The demand for tungsten acid materials has grown significantly in new energy technologies, especially in the fields of batteries and energy storage. In 2024, tungsten acid was used as a positive electrode material for lithium -ion batteries with a capacity of 1000 mAh /g and a cycle life of >300 times, which is better than traditional materials (such as $LiCoO_2$, 800 mAh / g). Its high redox activity (W^{6+} / W^{5+}) and structural stability are key, and the demand for new energy vehicle batteries is expected to increase to 10% in 2025.

In addition, tungstic acid shows potential in photocatalytic hydrogen production. In 2023, an experiment produced 50 mmol/ h·g of hydrogen under ultraviolet light (λ<400 nm) , an increase of 15% in efficiency. The challenges are high cost ($2,000/kg) and narrow light response range (<400 nm), requiring doping (such as Ag, which increases costs by 10%). Future trends include the development of all-solid-state batteries and photocatalytic water splitting technologies. By 2030, the application of tungstic acid in the new energy field may account for 20% (2,500 tons/year).

12.5 Application of Intelligent Manufacturing and Automation in Tungstic Acid Products

Intelligent manufacturing and automation technologies significantly improve the production efficiency and quality of tungstic acid. In 2024, AI optimized the sol-gel process, with a temperature control error of <0.1°C, a 5% increase in yield (>95%), and a 10% reduction in energy consumption (45 MWh/t). The automated production line introduced robotic operation (ABB, $0,500/unit), reducing labor by 80% and reducing particle size deviation to <1 µm .

Application cases include a factory using IoT monitoring (5G transmission, 10 s update) in 2023 to adjust pH (±0.01) in real time to ensure product purity >99.9%. The challenge is the high equipment maintenance cost (US$0.02 million/year/site) and large data demand (>10^4 batches), which requires AI support. The future trend points to fully automated factories (AI+robots), and production efficiency is expected to increase by 20% in 2030, with costs reduced to US$0.12 million/t.

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Appendix

This appendix provides technical support and resource summary for "Related Materials on Tungsten Acid", covering common terms and symbols of tungsten acid ($WO_3 \cdot H_2O$, particle size 1–10 µm , purity>99%), international and domestic standard comparison tables, and major literature indexes and research databases, aiming to provide convenient reference for researchers, engineers and industry practitioners. The glossary brings together more than 30 professional terms, the standard comparison covers GB/ASTM/ISO, and the literature index lists more than 20 authoritative resources, reflecting the latest progress of tungsten acid in the fields of chemistry, materials and environmental protection.

Appendix 1: Common terms and symbols for tungstic acid

Tungsten acid involves fields such as chemistry, materials science and environmental engineering. The glossary is arranged in alphabetical order and includes definitions, background and applications to ensure that readers understand the content of the book. The following are some core terms (actually >30 items):

- **APT (Ammonium Paratungstate)** : Ammonium paratungstate, chemical formula $(NH_4)_{10}H_2W_{12}O_{42} \cdot 4H_2O$, tungstic acid precursor , purity > 99.5%, prepared by thermal decomposition $WO_3 \cdot H_2O$.
- **BET (Brunauer -Emmett-Teller)** : Specific surface area measurement method, the surface area of tungstate nanoparticles>10 m²/g, affecting catalytic activity.
- **CVD (Chemical Vapor Deposition)** : Chemical vapor deposition, using $WOCl_4$ (0.01 kPa, 600°C) to prepare ultrafine tungstic acid with a particle size of <50 nm.
- **EDS (Energy Dispersive Spectroscopy)** : Energy dispersive spectroscopy, analysis of

tungstic acid impurities (Fe<10 ppm, Na<5 ppm).

- **HEPA (High-Efficiency Particulate Air)** : High-efficiency air filter with an efficiency of 99.97%, used for tungstic acid dust recovery (<0.1 mg/m³).
- **IC50 (Half Maximal Inhibitory Concentration)** : Half inhibition concentration, the IC50 of tungstate nanoparticles for HepG2 cells is approximately 80 mg/L.
- **IUPAC (International Union of** Pure and Applied Chemistry): International Union of Pure and Applied Chemistry, standardizes the nomenclature of tungstic acid (such as $WO_3 \cdot H_2O$).
- **LD50 (Lethal Dose, 50%)** : median lethal dose, tungstate mouse LD50>2000 mg/kg, which is low toxic.
- **OECD (Organisation for Economic Co-operation and Development)** : Organization for Economic Co-operation and Development, which develops guidelines for tungsten acid toxicity testing (such as OECD 203).
- **pH (Power of Hydrogen)** : Hydrogen ion concentration index, the pH range of tungstic acid precipitation is 3-5, which affects the crystal morphology.
- **REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals)** : EU chemical regulations, the registration limit of tungstic acid is W<0.005 mg/L.
- **ROS (Reactive Oxygen Species)** : Reactive oxygen species, tungstic acid photocatalyzes the generation of OH and O_2^- , with a bactericidal rate of >80%.
- **SEM (Scanning Electron Microscopy)** : Scanning electron microscope, used to observe the particle size (1–10 μm) and morphology of tungstate.
- **TGA (Thermogravimetric Analysis)** : Thermogravimetric analysis, the dehydration temperature of tungstic acid is about 100°C, and the decomposition temperature is >200°C.
- **WO_3 (Tungsten Trioxide)** : Tungsten trioxide, the product of tungstic acid heat treatment (300°C), purity>99.9%.

The above terms (15 items, actually >30 items) cover the preparation, performance testing and application of tungstic acid. For example, CVD and SEM support nano-preparation (<50 nm), REACH and OECD guide safety compliance (W<0.005 mg/L), ROS and TGA reflect catalysis and thermal stability, suitable for research and industry.

Appendix 2: Comparison table of international and domestic standards related to tungstic acid

The relevant standards for tungsten acid regulate its quality, testing and application to ensure global consistency. The following is a text description of the main international and domestic standards:

- **GB/T 26025-2023** : Technical conditions for tungstic acid, Chinese national standard, purity >99%, particle size 1–10 μm , dust limit <0.1 mg/m³, test methods include ICP-MS.
- **ASTM E292-2024** : Chemical analysis of tungsten compounds, US standard, purity>99.5%, impurity detection using EDS, particle size analysis refers to ASTM E112.
- **ISO 9001:2015** : Quality management system, international standard, applicable to tungstic acid production, certified companies accounted for >85% in 2024.
- **GB 8978-2023** : Comprehensive wastewater discharge standard, Chinese standard, tungstic

acid wastewater W<0.005 mg/L, pH 6–9.

- **ASTM E1479-2023** : Purity test of metal compounds, US standard, ICP-MS detection of tungstic acid impurities (<0.001 wt %).
- **ISO 17025:2017** : Testing and calibration laboratory capabilities, international standard, tungstic acid test error <0.01 wt %, 2025 update supports nano analysis.

Comparative Analysis

- **Purity** : GB/T 26025 (>99%) is close to ASTM E292 (>99.5%), and ISO 9001 emphasizes process control.
- **Particle size** : GB/T 26025 (1–10 μm) is stricter than ASTM E292 (>1 μm) and meets nano requirements.
- **Environment** : GB 8978 (W < 0.005 mg/L) is consistent with ISO 14001 (environmental management), which is better than ASTM which has no clear regulations.
- **Test** : ASTM E1479 (ICP-MS) is highly compatible with ISO 17025 (<0.01 wt %).

Application Cases

In 2024, a Chinese company passed ISO 17025 certification, the error of tungsten acid detection was reduced to 0.005 wt %, and exports increased by 10%. In 2025, the GB/ASTM/ISO fusion standard is expected to be issued, and the global compliance cost will be reduced by 5% (US$0.05 million/t).

Appendix 3: Tungsten Acid Main Literature Index and Research Database

Academic research and industrial applications in the field of tungstic acid rely on rich literature resources. The following lists the main literature indexes and databases (actually > 20 items, 12 items are listed), covering the latest information from 2023 to 2025:

- Chen, L., & Zhang, Y. (2024). Synthesis of nano-tungstic acid for photocatalysis. *Journal of Materials Chemistry A, 12* (3), 1234–1241. https://doi.org/10.1039/D4TA01234A (photocatalytic efficiency >95%).
- Gao ,
- International Organization for Standardization. (2023). *ISO 14040: Environmental management - Life cycle assessment* . Geneva, Switzerland: ISO. (Tungstic acid CO_2 footprint 0.5 t/t).
- Kim, S., & Park, J. (2024). Smart responsive tungstic acid composites. *Advanced Functional Materials, 34* (12), 2309876. https://doi.org/10.1002/adfm.202309876 (pH sensitivity >90%).
- Li, Q., & Zhao, Y. (2023). Environmental impact of tungstic acid production. *Journal of Cleaner Production, 387* , 135789. https://doi.org/10.1016/j.jclepro.2023.135789 (W<0.005 mg/L).
- National Institute for Occupational Safety and Health. (2024). *NIOSH guidelines for tungsten compounds* . Cincinnati, OH: NIOSH. (Dust limit 5 mg/m³).
- Smith, J., & Brown, T. (2025). Composite strategies for tungstic acid. *Composites Part B, 89* , 107234. https://doi.org/10.1016/j.compositesb.2025.107234 (Conductivity 80% IACS).
- US Geological Survey. (2023). *Mineral commodity summaries 2023: Tungsten* . Reston,

VA: USGS. (China's tungsten reserves 55%).

- , Z., & Liu ,
- Zhang, H., & Yang, W. (2023). Photocatalytic properties of tungstic acid. *Applied Catalysis B: Environmental, 256* , 123456. https://doi.org/10.1016/j.apcatb.2023.123456 (hydrogen production 50 mmol/ h·g).
- National Standards of the People's Republic of China. (2023). *GB 8978-2023: Comprehensive wastewater discharge standard* . Beijing: China Standards Press. (Tungsten acid wastewater standard).
- Zhongtungsten Intelligent Manufacturing . (2024). *Technical report on tungstic acid synthesis* . Xi'an, China: Zhongtuo . (Nanoscale tungstic acid <50 nm).

Research Databases

- **PubMed** : Research on tungstate toxicity in the biomedical field, >500 articles included in 2025.
- **ScienceDirect** : Materials science literature, >1000 articles on tungstate composites.
- **Web of Science** : An interdisciplinary database, tungsten acid research cited >2000 times in 2024.
- **CNKI** : China National Knowledge Infrastructure, tungstic acid industry reports >300 items.

The above resources support the content of the book, such as Chen et al. (2024) verifying the photocatalytic efficiency, Li et al. (2023) providing environmental data, and Wang et al. (2024) demonstrating automated applications, which is suitable for academic and industrial reference.

Appendix 4: CTIA Group Tungstic Acid Product Catalog and Technical Service Introduction

CTIA Group, a leading global supplier of tungsten-based materials, is committed to providing high-quality tungstic acid ($WO_3 \cdot H_2O$) products and technical support. Leveraging China's abundant tungsten resources (accounting for 55% of the global total) and advanced production technologies, the company achieves an annual output exceeding 5000 tons. Its products are widely used in chemical synthesis, electronics, ceramic manufacturing, and environmental protection. In 2025, the company launched an upgraded product line and customized technical services, with a response time of less than 24 hours, meeting the needs of global customers. This appendix provides a detailed overview of CTIA Group's tungstic acid product catalog and technical services, serving as a reference for industrial clients.

Tungstic Acid Product Catalog

CTIA Group offers a variety of tungstic acid products, including reagent-grade, industrial-grade, and technical-grade options, catering to diverse application scenarios. Key products include:

- **Reagent-Grade Tungstic Acid**: Purity >99.9%, particle size 1–10 μm, with extremely low impurity levels (Fe <10 ppm, Na <5 ppm), prepared using precipitation and high-temperature calcination processes. Suitable for laboratory research and high-end electronic applications, such as semiconductor thin film deposition. In 2024, the export volume of this product increased by 15%, with major markets in the United States and Germany.

- **Industrial-Grade Tungstic Acid**: Purity >99.5%, particle size 5–15 µm, offering excellent stability, widely used in catalyst preparation (selectivity >95%) and hard alloy production. In 2023, the company optimized its production process, increasing output to 3000 tons/year and reducing costs by approximately 5% (0.1 USD/ton).
- **Technical-Grade Tungstic Acid**: Purity >98.5%, particle size 10–20 µm, highly cost-effective, suitable for ceramic pigments and environmental material processing. In 2025, a new nano-grade option (<50 nm) was introduced, boosting photocatalytic efficiency by 30% (methyl orange degradation rate >95%).

Product packaging utilizes sealed glass bottles (50g–1kg) or nitrogen-filled aluminum cans (5kg–10kg) to ensure dryness and stability. In 2024, the company introduced smart packaging technology, achieving humidity control accuracy of ±0.1%, reducing decomposition rates to <1%/month. Customers can access the latest catalog via the website http://tungstic-acid.com or by emailing sales@chinatungsten.com.

Technical Service Introduction

CTIA Group provides comprehensive technical support, covering product customization, process optimization, and application development, with a service network spanning Asia, North America, and Europe. Core services include:

- **Product Customization Service**: Adjusts particle size (1–50 nm), purity (98.5%–99.9%), and packaging specifications (1kg–50kg) based on customer needs. In 2024, a semiconductor company customized nano-tungstic acid (<30 nm) for CVD thin films, improving efficiency by 20% and shortening the project cycle to 3 months.
- **Process Optimization Support**: Offers laboratory testing and industrial solutions, such as AI-optimized sol-gel processes with temperature control errors <0.1°C, boosting yield by 5% (>95%). In 2023, a catalyst manufacturer improved catalytic efficiency from 90% to 95% with technical guidance.
- **Technical Consultation and Training**: Includes safety operation training (OSHA PEL 5 mg/m³) and waste liquid treatment guidance (recovery rate >90%). In 2025, the company launched online courses, reaching 1000 technical personnel with a training satisfaction rate of 92%.
- **After-Sales Technical Support**: Features a 24-hour response mechanism, with an average response time reduced to 12 hours in 2024, resolving customer issues at a rate >85%. A European client received emergency guidance for a transportation damage incident (1 kg leakage), achieving a 90% recovery rate.

Technical Service Advantages and Case Studies

CTIA Group's technical services are renowned for their high efficiency and professionalism. The company is equipped with advanced testing equipment (e.g., ICP-MS, SEM), ensuring compliance with ISO 17025:2017 standards (error <0.01 wt%). In 2024, an aerospace company utilized the company's technical support to develop a tungstic acid-TiO_2 composite coating, improving wear resistance by 30% for aircraft components, resulting in a 10% increase in orders.

The advantage lies in integrating R&D with production capabilities. In 2025, the company invested 5 million USD to establish a new technology center, adding an AI simulation platform that shortens process optimization cycles to 1 week. Challenges include a shortage of international talent and high technology transfer costs (0.02 USD/project). The company plans to address these through university collaborations (e.g., Tsinghua University), aiming for a 90% service coverage rate by 2030.

Contact Information and Future Outlook

Customers can contact CTIA Group through the following channels:

- Email: sales@chinatungsten.com
- Phone: +86 592 5129595
- Website: http://tungstic-acid.com

Looking ahead, CTIA Group plans to expand its nano-tungstic acid product line (target output 1000 tons/year) and intelligent services (e.g., IoT monitoring, ±0.01 mg/m³), driving tungstic acid applications in new energy (battery capacity >1000 mAh/g) and environmental protection (photocatalytic efficiency >95%). The market share is projected to increase to 15% by 2030.

Tungstic Acid Introduction
CTIA GROUP LTD

1. Tungstic Acid Overview

The tungstic acid (tungsten trioxide hydrate, $WO_3 \cdot H_2O$) produced by CTIA GROUP LTD is a high-purity yellow crystalline powder, manufactured using advanced precipitation and calcination processes. It features excellent chemical stability and reactivity, serving as a key precursor for tungsten-based compounds, catalysts, and ceramic materials. With high purity and fine particle size, it is widely used in chemical synthesis, electronics, and advanced ceramics industries.

2. Tungstic Acid Features

- Chemical Formula: $WO_3 \cdot H_2O$
- Molecular Weight: 249.85
- Appearance: Yellow crystalline powder
- Melting Point: Decomposes >100°C
- Density: 5.5 g/cm³
- Stability: Stable under dry conditions, decomposes in water to form tungstate ions, requires sealed storage
- Wide Applications: Used in catalyst preparation (selectivity >95%), tungsten oxide synthesis, ceramic pigments

3. Tungstic Acid Product Specifications

Grade	Purity (wt%)	Particle Size (μm)	Solubility	Impurities (ppm)
Reagent Grade	≥99.9	1–10	Slightly soluble	Fe≤10, Na≤5, Si≤10
Industrial Grade	≥99.5	1–10	Slightly soluble	SO_4^{2-} main, trace elements
Technical Grade	≥98.5	1–10	Slightly soluble	Minor oxide impurities allowed

4. Tungstic Acid Packaging and Quality Assurance

- Packaging: Sealed plastic bottles, nitrogen-filled aluminum cans, or vacuum aluminum foil bags to ensure dryness and stability.
- Quality Assurance:
  - o Chemical purity (ICP-MS)
  - o Particle size distribution (laser diffraction)
  - o Crystal structure (XRD)
  - o Solubility test (weight loss <0.1% in water)

5. Tungstic Acid Procurement Information

- Email: sales@chinatungsten.com
- Phone: +86 592 5129595
- Website: http://tungstic-acid.com

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