Sodium Tungstate 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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Sodium Tungstate (Na_2WO_4) Product Introduction

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2. Sodium Tungstate Features

- **Chemical Composition**: $Na_2WO_4 \cdot 2H_2O$, sodium tungstate dihydrate. Purity ≥ 99.9%, with minimal impurities.
- **Appearance**: White or slightly yellowish crystalline powder; orthorhombic crystal structure.
- **High Solubility**: Solubility of 73 g/100 mL in water at 20°C, ideal for aqueous applications.
- **Versatility**: Supports applications in photocatalysis, battery materials, and heavy metal adsorption.
- **Stability**: Chemically stable under dry conditions, with consistent performance in industrial processes.

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5. Procurement Information

- **Email**: sales@chinatungsten.com
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Preface

"Encyclopedia of Sodium Tungstate" is a monograph that comprehensively and systematically introduces sodium tungstate (Na_2WO_4), aiming to provide authoritative and detailed reference materials for researchers, engineers, students and industry practitioners. As an important inorganic compound, sodium tungstate has shown unique value in the fields of industry, medicine, environment and new energy, and its research and application are constantly expanding. This preface will explain the purpose of writing this book, review the development history of sodium tungstate, introduce the structure of the book, and clarify the target readers and applicable scenarios.

1.1 Purpose and significance of compiling the Sodium Tungstate Encyclopedia

Sodium tungstate plays a key role in tungsten metallurgy, petrochemical industry, sewage treatment and diabetes research due to its excellent chemical stability, catalytic performance and biological activity. However, the existing literature is mostly presented in a scattered form and lacks systematic integration. This book aims to fill this gap and bring together the chemical properties, preparation methods, application fields, scientific research, industrial status and environmental impact of sodium tungstate, providing a one-stop resource for academic research and industrial applications. This book not only sorts out the theoretical and practical knowledge of sodium tungstate, but also looks forward to its development potential in cutting-edge fields such as new energy and nanotechnology, and strives to promote innovation and sustainable development in related fields.

1.2 Overview of the History and Development of Sodium Tungstate

The discovery and application of sodium tungstate can be traced back to the early 19th century, when chemists first synthesized sodium tungstate by extracting tungstic acid from tungsten ore and reacting it with sodium salt. In the early days, sodium tungstate was mainly used in analytical chemistry as a reagent for the determination of phosphates and proteins. In the 20th century, with the development of the tungsten metallurgical industry, sodium tungstate became an important intermediate for the production of ammonium paratungstate (APT) and tungsten powder. In recent years, the application research of sodium tungstate in biomedicine (such as insulin mimicking), environmental science (such as photocatalytic degradation of pollutants) and energy fields (such as sodium ion batteries) has grown rapidly. Technological progress and interdisciplinary integration have further expanded the application boundaries of sodium tungstate, making it the focus of modern materials science and green chemistry.

1.3 Structure and Usage Guide of Sodium Tungstate Encyclopedia

This book contains 17 chapters, covering the basic knowledge, preparation process, application fields, scientific research, industrial market, regulatory standards and environmental impact of sodium tungstate. Chapters 1 to 3 introduce the chemical and physical properties of sodium tungstate; Chapters 4 to 6 discuss its laboratory and industrial preparation; Chapters 7 to 10 detail its applications in industry, medicine, environment and emerging fields; Chapters 11 to 13 focus on theoretical and experimental research; Chapters 14 to 17 analyze the market, regulations and future trends. In addition, the appendix provides a glossary, references, data sheets and patent lists, and the index facilitates quick retrieval. Readers can choose chapters to read according to their needs, or read them in order to gain an in-depth understanding of the overall picture of sodium tungstate.

1.4 Target readers and applicable scenarios of Sodium Tungstate Encyclopedia

This book is intended for readers at multiple levels, including but not limited to:

- **Academic researchers** : Scholars and students in the fields of chemistry, materials science, environmental science, and biomedicine can refer to the theoretical research, experimental data, and patent list in this book.
- **Industrial practitioners** : Engineers and technicians in tungsten metallurgy, catalyst manufacturing, wastewater treatment and new energy industries can use preparation process, quality control and market analysis content to optimize production.
- **Policymakers** : Pay attention to the environmental impact and regulatory standards of sodium tungstate and formulate sustainable industrial policies.
- **Educators** : This book can be used as a reference in chemistry and materials science courses to inspire students ' interest in the applications of sodium tungstate.

This book is suitable for a variety of scenarios such as academic research, industrial development, policy making, and teaching and training. It aims to become an authoritative guide in the field of sodium tungstate .

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Chapter 1 Sodium Tungstate Introduction

Sodium Tungstate (Na_2WO_4) is an important inorganic compound. It is widely used in industry, medicine, environmental science and new energy due to its excellent chemical stability, catalytic performance and biological activity. This chapter aims to systematically introduce the basic definition, physical and chemical properties, crystal structure and characteristics of sodium tungstate and its related compounds, laying a theoretical foundation for the subsequent chapters to explore its preparation, application and research.

1.1 Definition and chemical formula of sodium tungstate

Sodium tungstate is an ionic compound composed of sodium ions (Na^+) and tungstate ions (WO_4^{2-}), with the chemical formula Na_2WO_4 . Tungsten (W) in the tungstate ion is in the +6 oxidation state, with a coordination number of 4, forming a tetrahedral structure. Sodium tungstate usually exists in anhydrous form (Na_2WO_4) or dihydrate form ($Na_2WO_4 \cdot 2H_2O$), and is widely used as an intermediate, catalyst precursor and biomedical reagent in tungsten metallurgy. Its molecular weight is 293.82 g/mol in anhydrous form and 329.85 g/mol in dihydrate. Sodium tungstate has high solubility in water and can form alkaline solutions with a pH value usually between 8-9, depending on the concentration and environmental conditions.

1.2 Physical properties of sodium tungstate

The physical properties of sodium tungstate vary slightly depending on its form (anhydrous or hydrate). The following are the main physical properties:

- **Appearance** : Anhydrous sodium tungstate is white or slightly yellow crystalline powder, and dihydrate is transparent or white orthorhombic crystal.
- **Density** : The density of anhydrous sodium tungstate is about 4.18 g/cm³, and the density of dihydrate is about 3.25 g/cm³.

- **Melting point** : The melting point of anhydrous sodium tungstate is 698°C. It can be decomposed into tungsten oxide (WO_3) and sodium oxide (Na_2O) at high temperature.
- **Solubility** : Sodium tungstate has high solubility in water, about 73 g/100 mL at 20°C, which increases slightly with increasing temperature; it is insoluble in organic solvents such as ethanol and ether.
- **Hygroscopicity** : The dihydrate is stable in the air, and the anhydrous form is slightly hygroscopic and needs to be stored in a sealed container. These physical properties make sodium tungstate easy to process and store, and suitable for a variety of industrial and experimental applications.

1.3 Chemical properties of sodium tungstate

The chemical properties of sodium tungstate are mainly determined by the tetrahedral structure of tungstate ions and the high oxidation state of tungsten , showing the following characteristics:

- **Acidity and alkalinity** : Sodium tungstate aqueous solution is weakly alkaline, because the tungstate ion is partially hydrolyzed to form tungstic acid hydroxide (HWO_4^-). It can react with strong acid to form insoluble tungstic acid (H_2WO_4), for example: $Na_2WO_4 + 2HCl \rightarrow H_2WO_4\downarrow + 2NaCl$.
- **Oxidation-reduction property** : Tungsten is stable at +6 valence, and sodium tungstate is not easily oxidized. However, under the action of a strong reducing agent (such as zinc powder), tungsten can be reduced to a low valence state to form blue tungsten oxide.
- **Complexing ability** : Tungstate ions can form stable complexes with a variety of metal ions (such as Fe^{3+}, Cu^{2+}) and are used in analytical chemistry and catalyst design.
- **Thermal stability** : Sodium tungstate is stable at room temperature, but begins to decompose when heated to above 700°C, generating tungsten oxide and sodium oxide.
- **Catalytic activity** : Sodium tungstate exhibits catalytic performance in oxidation reactions and is often used as a co-catalyst in petrochemicals and organic synthesis. These chemical properties determine the versatility of sodium tungstate in industrial catalysis, analytical chemistry and biomedicine.

1.4 Crystal structure and molecular properties of sodium tungstate

The crystal structure of sodium tungstate varies with its morphology. Anhydrous sodium tungstate usually has a cubic crystal structure (space group Fd-3m), with sodium ions and tungstate ions arranged by ionic bonds. Dihydrate ($Na_2WO_4 \cdot 2H_2O$) is an orthorhombic crystal (space group Pnma) , in which water molecules are bonded to tungstate ions and sodium ions by hydrogen bonds, enhancing the stability of the crystal .

Tungstate ion (WO_4^{2-}) is in a regular tetrahedral configuration, with a WO bond length of about 1.78 Å and a bond angle of nearly 109.5°. Infrared spectroscopy (IR) shows that the characteristic absorption peak of tungstate is at 800-900 cm^{-1}, which is attributed to the stretching vibration of WO. X-ray diffraction (XRD) analysis shows that the lattice parameters of sodium tungstate are similar to those of calcium tungstate ($CaWO_4$), reflecting the structural commonality of tungstates. Molecular dynamics simulation further reveals that sodium tungstate maintains a tetrahedral structure in aqueous solution, but may form polytungstates (such as $[W_2O_7]^{2-}$) at high concentrations, affecting its chemical behavior.

1.5 Isomers and related compounds of sodium tungstate

Sodium tungstate itself has no isomers, but compounds with similar chemical properties include other tungstates and tungstic acid derivatives, mainly as follows:

- **Other tungstates : such as** potassium tungstate (K_2WO_4) and ammonium tungstate ($(NH_4)_2WO_4$) , have similar chemical properties but different solubility and crystal structure , and are used in catalysts and pigments.
- **Polytungstate** : Sodium tungstate can be polymerized into polynuclear tungstates under acidic conditions, such as sodium hexatungstate ($Na_6[W_6O_{19}]$), which is used in photocatalytic materials.
- **Tungstic acid : Tungstic acid (** H_2WO_4) generated by the reaction of sodium tungstate and acid is a yellow precipitate and is an important intermediate in tungsten metallurgy.
- **Tungsten oxide** : The high-temperature decomposition product, tungsten oxide (WO_3), is widely used in electrochromic devices and energy storage materials.
- **Sodium tungstate complexes** : such as complexes formed by sodium tungstate and organic ligands, which are used in biomedicine and nanotechnology. The properties of these related compounds are closely related to sodium tungstate, and together they constitute a rich system of tungsten chemistry, providing diverse options for subsequent application research.

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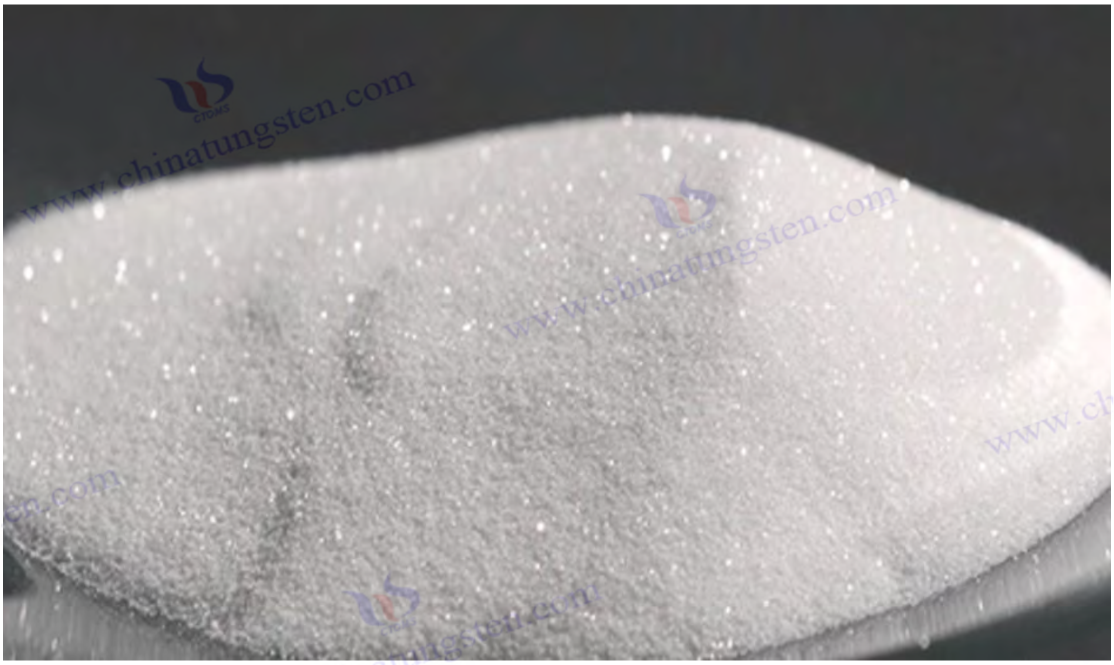

Chapter 2 Classification and form of sodium tungstate

Sodium tungstate (Na_2WO_4) is a multi-purpose inorganic compound, and its form and classification directly affect its application in industry, scientific research and medical fields. This chapter systematically introduces the anhydrous form and hydrate of sodium tungstate, different purity grades, solution and solid forms, as well as packaging and storage requirements, providing a basis for the subsequent discussion of its preparation process and application scenarios.

Anhydrous form and dihydrate of sodium tungstate ($Na_2WO_4 \cdot 2H_2O$)

Sodium tungstate mainly exists in anhydrous form (Na_2WO_4) and dihydrate form ($Na_2WO_4 \cdot 2H_2O$), both of which have their own characteristics in structure and application. Anhydrous sodium tungstate is a white or slightly yellow crystalline powder with a molecular weight of 293.82 g/mol, a density of about 4.18 g/cm³, and a melting point of 698°C. It is usually used in high-temperature processes or scenarios requiring high-purity raw materials, such as tungsten powder preparation and catalyst synthesis. The dihydrate is a transparent or white orthorhombic crystal with a molecular weight of 329.85 g/mol and a density of about 3.25 g/cm³. It is more stable at room temperature, easy to store and transport, and is often used in laboratory analysis and aqueous solution preparation. The two water molecules of the dihydrate are bonded to the tungstate ion through hydrogen bonds, and can be dehydrated to anhydrous form when heated to above 100°C. Both forms are soluble in water, but the dihydrate is less hygroscopic in a humid environment and is suitable for long-term storage.

2.2 Different purity levels of sodium tungstate (industrial grade, analytical grade, pharmaceutical grade)

Sodium tungstate is classified into different purity grades according to its usage and impurity content, mainly including industrial grade, analytical grade and pharmaceutical grade:

- **Industrial grade** : The purity is usually 98%-99%, containing trace impurities such as molybdenum (Mo) and iron (Fe), suitable for tungsten metallurgy (such as ammonium paratungstate production), catalyst preparation and pigment manufacturing. The cost is low and meets large-scale industrial needs.
- **Analytically pure (AR)** : Purity ≥ 99.5%, impurity content is strictly controlled (such as Mo < 0.01%), used for laboratory analysis, such as phosphate determination and biochemical experiments. Analytically pure sodium tungstate needs to go through multiple steps of purification, such as ion exchange or recrystallization.
- **Pharmaceutical grade** : Purity ≥ 99.9%, in line with pharmacopoeia standards (such as USP or CP), with extremely low content of heavy metals and microorganisms, used for biomedical research (such as diabetes treatment) and drug development. The production of pharmaceutical grade sodium tungstate must comply with GMP (Good Manufacturing Practice) requirements. The choice of different purity levels depends on the application scenario, for example, industrial grade is suitable for cost-sensitive scenarios, while pharmaceutical grade prioritizes safety and biocompatibility.

2.3 Solution and solid forms of sodium tungstate

Sodium tungstate can exist in solid or solution form according to the requirements of use. Solid forms include anhydrous sodium tungstate powder and dihydrate crystals, which are easy to store, transport and accurately weigh, and are suitable for catalyst preparation, powder metallurgy and laboratory synthesis. The solution form is usually an aqueous solution of sodium tungstate, with a concentration range from dilute solution (1-5% w/v) to saturated solution (about 40% w/v at 20°C), which is widely used in sewage treatment, biological experiments and electroplating processes. Sodium tungstate solution is weakly alkaline (pH 8-9), and crystals may precipitate at high concentrations. Temperature and pH need to be controlled to maintain stability. In specific applications, such as photocatalysis or battery research, sodium tungstate solution can be mixed with organic solvents (such as ethylene glycol) to form a colloidal or precursor solution. The conversion between solid and solution forms needs to consider the dissolution heat effect and the risk of impurity introduction.

2.4 Packaging and storage requirements of sodium tungstate

The packaging and storage of sodium tungstate directly affect its quality and service life. The following are the main requirements:

- **Packaging** : Solid sodium tungstate is usually packaged in sealed plastic bags, polyethylene barrels or glass bottles, lined with moisture-proof materials to avoid moisture absorption and contamination. Industrial-grade products are mostly packaged in 25 kg or 50 kg barrels, while analytical-grade and pharmaceutical-grade products are mainly packaged in small packages of 100 g to 1 kg. Solutions are packaged in corrosion-resistant plastic barrels or glass containers, marked with concentration and batch number.
- **Storage conditions** : Sodium tungstate should be stored in a cool, dry, ventilated environment, with the temperature controlled at 5-30°C and relative humidity below 60%. Anhydrous sodium tungstate needs to be especially moisture-proof, while dihydrate is relatively stable but should be kept away from high temperatures. The solution needs to be

stored in a sealed container to prevent volatilization or crystallization .

- **Safety Note** : Sodium tungstate is a low-toxic chemical, but contact with the skin or inhalation of dust may cause irritation, and the storage area must be equipped with protective equipment. Pharmaceutical-grade products must be stored in isolation to avoid cross contamination.
- **Shelf life** : Under appropriate conditions, the shelf life of solid sodium tungstate can reach 2-3 years. The solution form is recommended to be used within 6-12 months, and the pH and impurity content should be tested regularly. Standardized packaging and storage ensure the stability and safety of sodium tungstate in industrial production, laboratory research and medical applications.

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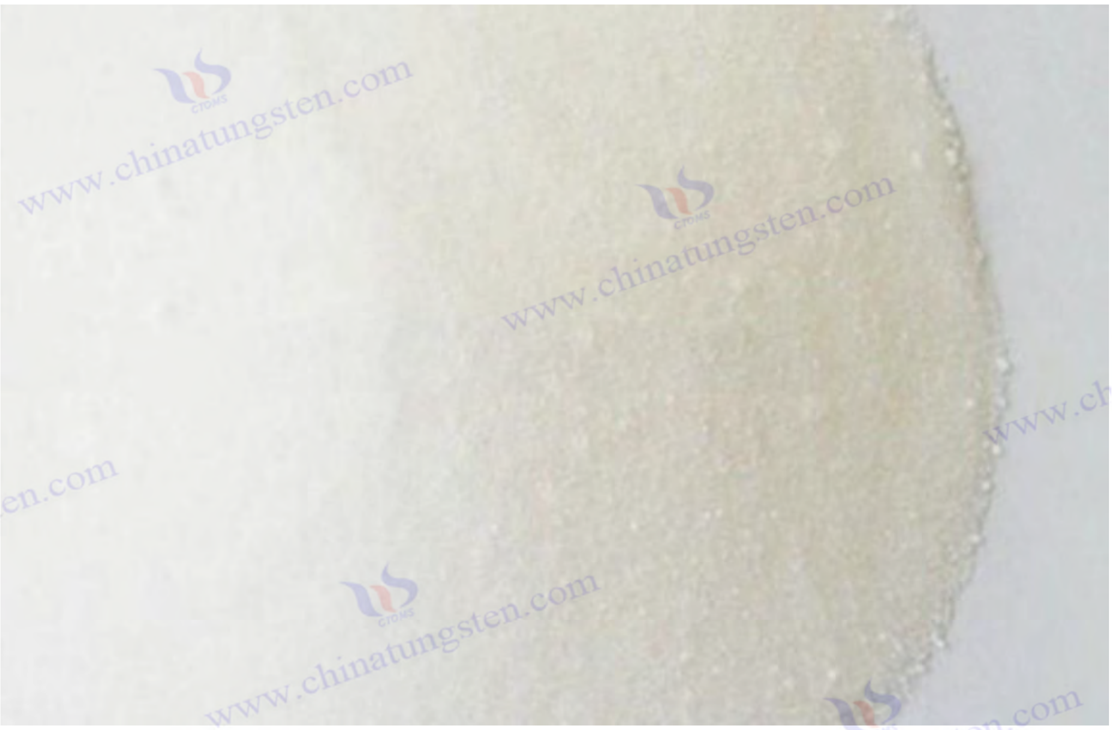

Chapter 3 Chemical reaction of sodium tungstate

Sodium tungstate (Na_2WO_4) is a chemically active inorganic compound, and its reaction characteristics are of great significance in industrial production, analytical chemistry and catalysis. This chapter systematically discusses the reaction of sodium tungstate with acid, complex reaction with metal ions, redox characteristics, thermal decomposition and high temperature reaction, as well as its catalytic effect and reaction mechanism, to provide theoretical support for subsequent preparation process and application research.

3.1 Reaction of sodium tungstate with acid (generating tungstic acid, etc.)

Sodium tungstate is weakly alkaline (pH 8-9) in aqueous solution, and reaction with acid is one of its most common chemical behaviors. When sodium tungstate reacts with strong acid (such as hydrochloric acid, sulfuric acid), the tungstate ion (WO_4^{2-}) is protonated to generate insoluble tungstic acid (H_2WO_4) precipitation. The reaction equation is as follows:

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

Tungstic acid is a yellow solid, slightly soluble in water (solubility is about 0.02 g/100 mL), stable in an acidic environment, and often used as an intermediate in tungsten metallurgy. The reaction rate is affected by acid concentration, temperature, and stirring conditions. High acid concentrations can accelerate precipitation formation. In addition, sodium tungstate reacts slowly with weak acids (such as acetic acid) and may form partially protonated intermediates (such as HWO_4^-). Under strong acidic conditions, tungstic acid may further polymerize into polytungstic acids (such as $H_2W_{12}O_{40}$), which are used to prepare polyacid catalysts.

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3.2 Complexation reaction of sodium tungstate and metal ions

The tungstate ion of sodium tungstate has strong coordination ability and can form stable complexes with a variety of metal ions (such as Fe^{3+}, Cu^{2+}, Ni^{2+}), which are widely used in analytical chemistry and catalyst design. For example, tungstate reacts with iron (III) ions to form soluble iron tungstate complexes, which are often used as protein precipitants. The reaction formula is as follows:

$$Fe^{3+} + WO_4^{2-} \rightarrow [Fe(WO_4)]^{+}$$

In analytical chemistry, sodium tungstate competitively binds to metal ions with molybdate (MoO_4^{2-}) and phosphate (PO_4^{3-}) to form isopolyacid structures for spectral analysis and colorimetric determination. In addition, complexes of sodium tungstate with transition metal ions (such as Co^{2+} , Mn^{2+}) show excellent performance in catalytic oxidation reactions, and the stability of the complexes is often characterized by ultraviolet-visible spectroscopy (UV-Vis) and infrared spectroscopy (IR). The selectivity of the complex reaction is affected by pH, ion concentration and ligand competition, and the reaction conditions need to be precisely controlled.

3.3 Redox reaction characteristics of sodium tungstate

The tungsten in sodium tungstate is in the +6 oxidation state (W^{6+}) , which is the highest oxidation state. Therefore, it is not easily oxidized under normal conditions, but can be reduced to a low valence state (such as W^{5+} or W^{4+}) by a strong reducing agent . For example , in an acidic solution, sodium tungstate reacts with zinc powder to form blue tungsten oxide (W_2O_5 or WO_2) , and the reaction is as follows:

$$Na_2WO_4 + Zn + 2H^{+} \rightarrow W_2O_5 + Zn^{2+} + 2Na^{+} + H_2O$$

This blue oxide has semiconductor properties and is used in electrochromic materials and sensors. The redox potential of sodium tungstate is about -0.1 V (relative to the standard hydrogen electrode), which is affected by the solution pH and the ligand environment. In catalytic applications, sodium tungstate is often used as a carrier of oxidants to promote the selective oxidation of organic matter by synergistically acting with hydrogen peroxide (H_2O_2) or oxygen . Electrochemical studies have shown that sodium tungstate can undergo reversible single electron transfer on the electrode surface, which is suitable for energy storage and electrocatalysis.

3.4 Thermal decomposition and high temperature reaction of sodium tungstate

Sodium tungstate is chemically stable at room temperature, but it will decompose or change phase at high temperature. Anhydrous sodium tungstate starts to melt when heated to about 698°C, and decomposes into tungsten oxide (WO_3) and sodium oxide (Na_2O) when further heated to above 800°C. The reaction is as follows:

$$Na_2WO_4 \rightarrow WO_3 + Na_2O$$

The dihydrate ($Na_2WO_4 \cdot 2H_2O$) first loses crystal water at 100-150°C and converts to anhydrous form . Thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC) show that the decomposition process of sodium tungstate is an endothermic reaction, and the morphology and purity of the decomposition product are affected by the heating rate and atmosphere (such as air or inert gas). In a high-temperature reducing atmosphere (such as H_2) , sodium tungstate can directly generate metallic tungsten, which is widely used in tungsten powder production. In addition, sodium tungstate reacts with carbonates or silicates at high temperatures to generate tungstate-based ceramic materials, which are used in high-temperature structural materials.

3.5 Catalytic effect and reaction mechanism of sodium tungstate

Sodium tungstate exhibits excellent performance in a variety of catalytic reactions, especially in oxidation, dehydration and esterification reactions. Its catalytic activity mainly comes from the Lewis acidity and coordination ability of the tungstate ion. For example, sodium tungstate combines with hydrogen peroxide to form peroxytungstic acid ($[WO(O_2)_2]^{2-}$), which can catalyze the oxidation of alcohols to aldehydes or ketones. The reaction mechanism is as follows:

1. **Active species generation** : Tungstate coordinates with H_2O_2 to form peroxytungstic acid.
2. **Substrate oxidation** : The oxygen atom in peroxytungstic acid is transferred to the substrate (such as alcohol) to generate an oxidation product.
3. **Catalyst regeneration** : Tungstate returns to its initial state and catalysis continues.

In petrochemicals, sodium tungstate is used as a co-catalyst to promote olefin epoxidation and aromatic hydroxylation. In the field of photocatalysis, sodium tungstate is compounded with semiconductor materials (such as TiO_2) to enhance visible light response and degrade organic pollutants. The catalytic reaction mechanism is studied by density functional theory (DFT) and in situ spectroscopy (such as Raman, XPS), revealing the electron transfer and surface active sites of tungstate. The catalytic efficiency is affected by pH, temperature and co-catalyst, and the reaction conditions need to be optimized to achieve efficient conversion.

CTIA GROUP LTD
Sodium Tungstate (Na_2WO_4) Product Introduction

1. Sodium Tungstate Overview

CTIA GROUP Sodium Tungstate (Na_2WO_4, Sodium Tungstate Dihydrate, referred to as ST) is produced using an advanced wet metallurgical process. Na_2WO_4 is a white crystalline powder widely used in catalysis, electroplating, environmental applications, and advanced materials due to its high purity, solubility, and chemical stability. Its tungstate ion (WO_4^{2-}) enables versatile applications in industries ranging from chemical manufacturing to renewable energy.

2. Sodium Tungstate Features

- **Chemical Composition**: $Na_2WO_4 \cdot 2H_2O$, sodium tungstate dihydrate. Purity ≥ 99.9%, with minimal impurities.
- **Appearance**: White or slightly yellowish crystalline powder; orthorhombic crystal structure.
- **High Solubility**: Solubility of 73 g/100 mL in water at 20°C, ideal for aqueous applications.
- **Versatility**: Supports applications in photocatalysis, battery materials, and heavy metal adsorption.
- **Stability**: Chemically stable under dry conditions, with consistent performance in industrial processes.

3. Product Specifications

Type	Particle Size (μm)	Purity (wt%)	Bulk Density (g/cm³)	WO_3 Content (wt%)	Impurities (wt%, max)
Fine Grade	5-10	≥99.9	3.8-4.0	68.00	Fe≤0.001, Mo≤0.002
Standard Grade	10-15	≥99.9	4.0-4.2	68.00	Fe≤0.001, Mo≤0.002
Coarse Grade	15-20	≥99.9	4.2-4.4	68.00	Fe≤0.001, Mo≤0.002

4. Packaging and Quality Assurance

- **Packaging**: Sealed plastic bottles or vacuum aluminum foil bags, net weight 500g, 1kg, or 5kg, ensuring moisture-proof and oxidation-proof storage.
- **Quality Assurance**: Each batch includes a quality certificate with data on purity (ICP-MS), particle size distribution (laser diffraction), crystal structure (XRD), and WO_3 content (titration).

5. Procurement Information

- **Email**: sales@chinatungsten.com
- **Tel**: +86 592 5129595
- **Website**: For more information about sodium tungstate, please visit the China Tungsten Online website (www.sodium-tungstate.com).

Chapter 4 Laboratory Preparation Method of Sodium Tungstate

Sodium tungstate (Na_2WO_4) is an important chemical reagent with various laboratory preparation methods suitable for different research and teaching needs. This chapter systematically introduces the extraction of sodium tungstate from tungsten ore, chemical synthesis (reaction of tungstic acid and sodium hydroxide), electrochemical preparation technology, laboratory purification and crystallization technology, and safety precautions during the preparation process, providing practical guidance for researchers and laying the foundation for the subsequent industrial production chapter (Chapter 5).

4.1 Extraction of Sodium Tungstate from Tungsten Ore

Tungsten ore (such as scheelite $CaWO_4$ or wolframite $FeWO_4$) is the main raw material for preparing sodium tungstate. Laboratory extraction usually adopts alkaline leaching method. First, the crushed tungsten ore reacts with sodium hydroxide (NaOH) solution at high temperature (100-150°C) to generate soluble sodium tungstate. The reaction is as follows:

$$CaWO_4 + 2NaOH \rightarrow Na_2WO_4 + Ca(OH)_2 \downarrow$$

$Ca(OH)_2$ generated by the reaction is a precipitate, which is separated by filtration. The solution may contain impurities such as silicon and phosphorus, which need to be neutralized with acid to pH 8-9. After the impurities are precipitated, a crude sodium tungstate solution is obtained. Subsequently, sodium tungstate dihydrate ($Na_2WO_4 \cdot 2H_2O$) is obtained by evaporation crystallization or adding ethanol to promote precipitation. This method is suitable for preparing sodium tungstate from natural minerals with a yield of about 85%-90%, but the alkali concentration and reaction time need to be controlled to avoid the accumulation of by-products.

4.2 Chemical synthesis of sodium tungstate (reaction of tungstate with sodium hydroxide)

The chemical synthesis method uses tungstic acid (H_2WO_4) or tungsten oxide (WO_3) as raw materials and reacts with sodium hydroxide to produce sodium tungstate, which is suitable for small-scale laboratory preparation of high-purity products. The typical reaction is as follows:

$H_2WO_4 + 2NaOH \rightarrow Na_2WO_4 + 2H_2O$

or

$WO\ 2 + 2NaOH \rightarrow Na_2WO_4 + H_2O$

Experimental steps:

1. Add appropriate amount of deionized water to tungstic acid or tungsten oxide and stir to form a suspension.
2. Slowly add sodium hydroxide solution (1-2 M) and heat to 80-100 °C, stirring until the solid is completely dissolved.
3. The solution is filtered to remove unreacted impurities, and the resulting clear solution is cooled and crystallized or concentrated under reduced pressure to obtain sodium tungstate crystals.
4. Wash the crystals with a small amount of cold water and dry them to obtain $Na_2WO_4 \cdot 2H_2O$ with a purity of ≥99% .

This method is simple to operate, with a yield of more than 90%, and is suitable for the preparation of analytically pure or pharmaceutical grade sodium tungstate. The use of high-purity raw materials and control of pH (8-10) can further improve product quality.

4.3 Electrochemical preparation technology of sodium tungstate

The electrochemical method prepares sodium tungstate by electrolyzing tungsten or tungsten compounds, which is environmentally friendly and efficient. The experimental device usually includes a tungsten metal anode, a stainless steel cathode, and a sodium hydroxide (NaOH) electrolyte solution (0.5-1 M). Under the action of direct current (voltage 5-10 V), the tungsten anode is oxidized and dissolved to generate tungstate ions, which combine with sodium ions in the solution to generate sodium tungstate. The reaction is as follows:

$W + 4OH^- \rightarrow WO_4^{2-} + 2H_2O + 4e^-$

$2Na^+ + WO_4^{2-} \rightarrow Na_2WO_4$

During the electrolysis process, hydrogen is generated at the cathode, and ventilation is required to ensure safety. After the electrolyte is filtered to remove trace insoluble impurities, sodium tungstate

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is obtained by evaporation and crystallization. The advantage of the electrochemical method is that the raw material utilization rate is high (close to 95%), which is suitable for the preparation of high-purity sodium tungstate, but the equipment cost is relatively high, and the current density (0.1-0.5 A/cm²) and electrolysis time need to be optimized to improve efficiency.

4.4 Laboratory Purification and Crystallization Technology of Sodium Tungstate

Sodium tungstate prepared in the laboratory often contains trace impurities (such as molybdenum , iron, and calcium), and needs to be purified to improve its quality. Common purification methods include:

- **Recrystallization** : Dissolve the crude sodium tungstate in hot water (60-80°C), filter to remove insoluble matter, and cool to room temperature to precipitate crystals. Repeat 2-3 times to increase the purity to more than 99.5%.
- **Ion exchange** : Use cation exchange resin (such as Amberlite IR-120) to remove metal impurities, or anion exchange resin to remove silicate and phosphate. The solution pH is controlled at 7-9 to maintain the stability of tungstate .
- **Precipitation separation** : Add ammonium sulfide ($(NH_4)_2S$) to precipitate molybdenum sulfide (MoS_2) , and then filter to obtain pure sodium tungstate solution.

In terms of crystallization technology, the slow cooling method can obtain large dihydrate crystals, while the rapid evaporation method is suitable for preparing small crystals. Crystal drying is carried out in a vacuum oven at 50-60°C to avoid high-temperature dehydration. The impurity content needs to be monitored during the purification and crystallization process (such as ICP-MS detection) to ensure that it meets analytical purity or pharmaceutical grade standards.

4.5 Safety precautions in the preparation of sodium tungstate

The preparation of sodium tungstate involves strong alkali, high temperature and electrochemical operation, and safety regulations must be strictly followed:

- **Chemical safety** : Sodium hydroxide is highly corrosive, so wear protective glasses, gloves and lab coats when operating. Sodium tungstate dust may irritate the respiratory tract and needs to be handled in a fume hood.
- **High temperature operation** : Use a constant temperature water bath or hot plate to heat the reaction (100-150°C) to avoid splashing of the solution. Avoid burns when cooling and crystallizing.
- **Electrochemical safety** : The electrolysis device must be grounded, and the electrodes and lines must be checked regularly. Hydrogen must be discharged through the exhaust system to avoid accumulation and explosion.
- **Waste liquid treatment** : Tungsten-containing waste liquid is a heavy metal waste and needs to be neutralized to pH 6-8 and properly disposed of after precipitating tungstic acid in accordance with environmental protection regulations (such as GB/T 30810).
- **Storage and labeling** : The prepared sodium tungstate should be stored in a sealed container and marked with the chemical name, purity and preparation date to avoid misuse.

Through standardized operations, the preparation process can be ensured to be safe and efficient, and the product quality can be stable.

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Sodium Tungstate (Na_2WO_4) Product Introduction

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2. Sodium Tungstate Features

- **Chemical Composition**: $Na_2WO_4 \cdot 2H_2O$, sodium tungstate dihydrate. Purity ≥ 99.9%, with minimal impurities.
- **Appearance**: White or slightly yellowish crystalline powder; orthorhombic crystal structure.
- **High Solubility**: Solubility of 73 g/100 mL in water at 20°C, ideal for aqueous applications.
- **Versatility**: Supports applications in photocatalysis, battery materials, and heavy metal adsorption.
- **Stability**: Chemically stable under dry conditions, with consistent performance in industrial processes.

3. Product Specifications

Type	Particle Size (μm)	Purity (wt%)	Bulk Density (g/cm³)	WO_3 Content (wt%)	Impurities (wt%, max)
Fine Grade	5-10	≥99.9	3.8-4.0	68.00	Fe≤0.001, Mo≤0.002
Standard Grade	10-15	≥99.9	4.0-4.2	68.00	Fe≤0.001, Mo≤0.002
Coarse Grade	15-20	≥99.9	4.2-4.4	68.00	Fe≤0.001, Mo≤0.002

4. Packaging and Quality Assurance

- **Packaging**: Sealed plastic bottles or vacuum aluminum foil bags, net weight 500g, 1kg, or 5kg, ensuring moisture-proof and oxidation-proof storage.
- **Quality Assurance**: Each batch includes a quality certificate with data on purity (ICP-MS), particle size distribution (laser diffraction), crystal structure (XRD), and WO_3 content (titration).

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Chapter 5 Industrial production process of sodium tungstate

Sodium Tungstate (Na_2WO_4) is an important intermediate in tungsten metallurgy and chemical industry. Its industrial production process directly affects product quality, cost and environmental benefits. This chapter systematically introduces the raw material selection, hydrometallurgical process, roasting and dissolution process, industrial crystallization and drying technology, production equipment and automation control, as well as by-product treatment and recycling of sodium tungstate industrial production, providing a comprehensive reference for industrial practitioners and researchers.

5.1 Selection of raw materials for sodium tungstate (scheelite, wolframite, waste tungsten material)

of sodium tungstate mainly include scheelite ($CaWO_4$), wolframite ((Fe,Mn)WO_4) and waste tungsten materials (such as waste catalysts and waste alloys). Scheelite contains about 50%-70% tungsten (in terms of WO_3), which is easy to react with alkali and suitable for hydrometallurgy, and is the main raw material. Wolframite contains slightly lower tungsten (40%-60%) and needs to be pretreated to remove iron and manganese. It is often used in roasting processes. The tungsten content of waste tungsten materials varies greatly (10%-90%) and needs to be classified and recycled, which is suitable for the circular economy.

Key factors in raw material selection include:

- **Tungsten content** : High-grade ores (WO_3 >50%) are preferred to reduce processing costs.
- **Impurities** : Impurities such as silicon, phosphorus, and molybdenum need to be controlled to reduce purification steps.

- **Particle size** : The ore is crushed to 100-200 mesh to improve the reaction efficiency.
- **Sustainability** : Recycling of waste tungsten can reduce dependence on minerals and meet environmental protection requirements.

As the world's largest tungsten producer, China has rich reserves of scheelite in Hunan and Jiangxi , providing a stable raw material for the production of sodium tungstate.

5.2 Hydrometallurgical process of sodium tungstate (alkaline leaching, ion exchange)

Hydrometallurgy is the mainstream process for industrial production of sodium tungstate, usually using alkaline leaching combined with ion exchange. The alkaline leaching method reacts scheelite or wolframite with sodium hydroxide (NaOH) or sodium carbonate (Na_2CO_3) solution at high temperature and high pressure (120-200°C, 0.5-2 MPa) to generate sodium tungstate solution. The typical reaction is as follows:

$CaWO_4 + 2NaOH \rightarrow Na_2WO_4 + Ca(OH)_2 \downarrow$

or

$CaWO_4 + Na_2CO_3 \rightarrow Na_2WO_4 + CaCO_3 \downarrow$

After the reaction, the insoluble calcium salt ($Ca(OH)_2$ or $CaCO_3$) is filtered to remove the crude sodium tungstate solution. The solution often contains impurities such as silicate, phosphate and molybdate , which need to be purified by ion exchange. Use a strong alkaline anion exchange resin (such as D201) to selectively adsorb WO_4^{2-} , and obtain a high-purity sodium tungstate solution after elution. The wet process has a yield of 90%-95% and low energy consumption, but it needs to treat a large amount of alkaline waste liquid, and the pH is controlled at 8-10 to optimize the separation efficiency.

5.3 Calcination and Dissolution Process of Sodium Tungstate

The roasting process is suitable for wolframite or low-grade ore. The ore must first be mixed with sodium carbonate (Na_2CO_3) and roasted at 800-1000°C to produce soluble sodium tungstate. The reaction is as follows:

$(Fe,Mn)WO_4 + Na_2CO_3 \rightarrow Na_2WO_4 + (Fe,Mn)CO_3$

The roasted product is leached with hot water (60-80°C) to dissolve the sodium tungstate and filter to remove insoluble iron and manganese compounds. The leachate is acidified (pH 7-8) to precipitate impurities such as silicon and phosphorus, and then the pH is adjusted to 9-10 with sodium hydroxide to promote the crystallization of sodium tungstate. The roasting process is suitable for processing complex ores, but the energy consumption is high, and the waste gas (CO_2) and solid slag need to be properly handled. The roasting equipment is usually a rotary kiln or a multi-chamber furnace , and the temperature and atmosphere need to be precisely controlled to avoid the volatilization of sodium tungstate.

5.4 Industrial Crystallization and Drying Technology of Sodium Tungstate

Industrial crystallization of sodium tungstate is usually achieved by evaporation crystallization or cooling crystallization. Evaporation crystallization concentrates the sodium tungstate solution to saturation under reduced pressure (0.01-0.05 MPa, 80-100°C) to precipitate dihydrate crystals ($Na_2WO_4 \cdot 2H_2O$). Cooling crystallization slowly cools the hot solution (80°C) to 20-30°C to obtain large-particle crystals, which are suitable for high-purity products. The crystallization process needs to control the cooling rate (1-2°C/min) and stirring speed (100-200 rpm) to ensure uniform crystals.

Drying technologies include:

- **Hot air drying** : Drying at 100-120°C, suitable for industrial-grade products, takes 2-4 hours.
- **Vacuum drying** : Drying at 50-60°C and 0.01 MPa is suitable for analytical or pharmaceutical grade products and retains crystal water.
- **Spray drying** : spray the sodium tungstate solution into microparticles and directly dry them into anhydrous powder, which is highly efficient but has high equipment cost.

dried sodium tungstate needs to be tested for moisture content (<0.5%) and particle size (50-200 μm) to ensure compliance with standards (such as GB/T 26037).

5.5 Sodium tungstate production equipment and automation control

of sodium tungstate involves a multi-step process that requires special equipment and automated control systems:

- **Reaction equipment** : autoclave (alkaline leaching), rotary kiln (roasting), resistant to high temperature and pressure, made of stainless steel or titanium alloy.
- **Separation equipment** : Plate and frame filter press (solid-liquid separation), ion exchange column (purification), with a processing capacity of 10-100 m^3/h.
- **Crystallization and drying equipment** : multiple-effect evaporator (crystallization), fluidized bed dryer (drying), energy-saving design to reduce energy consumption.
- **Automation control** : PLC (Programmable Logic Controller) system monitors temperature, pressure, pH and flow rate with an accuracy of ±0.5°C and ±0.01 MPa. Sensors detect solution concentration (WO_4^{2-}) in real time to ensure stable product quality.

The automation system can realize remote operation through SCADA (Supervisory Control and Data Acquisition), reduce manual intervention and improve production efficiency. Equipment maintenance requires regular cleaning to prevent scaling of sodium tungstate.

5.6 Treatment and recycling of sodium tungstate byproducts

Sodium tungstate production produces a variety of by-products that need to be properly handled to reduce environmental impact and achieve resource recycling:

- **Solid by-products** : Calcium salts ($Ca(OH)_2$, $CaCO_3$) can be used in cement or lime production; iron and manganese compounds are recovered through magnetic separation and used in steel smelting.
- **Liquid by-products** : The waste liquid containing molybdenum and phosphorus is recovered as sodium molybdate (Na_2MoO_4) through precipitation or ion exchange , and the

wastewater is neutralized (pH 6-8) to meet the discharge standards .

- **Gas by-products :** CO_2 produced by roasting is processed through carbon capture technology or used for sodium carbonate regeneration.
- **Recycling : Waste tungsten materials (such as waste catalysts)** can be regenerated into sodium tungstate raw materials through acid leaching or roasting, with a recovery rate of 80%-90%. Unreacted NaOH or Na_2CO_3 solution in production can be recycled to reduce costs.

By-product treatment must comply with environmental regulations (such as GB 25467) and adopt clean production technologies, such as zero-discharge system (ZLD), to achieve sustainable development.

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3. Product Specifications

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Chapter 6 Quality Control and Testing of Sodium Tungstate

sodium tungstate (Na_2WO_4) is a key link to ensure that it meets the requirements of industrial, scientific research and medical applications. Product quality directly affects its performance and safety, so precise analytical techniques and standardized processes are required. This chapter systematically introduces the analytical method of sodium tungstate purity, impurity detection, crystal morphology and particle size analysis, solution pH and concentration determination, as well as international and domestic testing standards, to provide technical support for quality management and application.

6.1 Analysis method of sodium tungstate purity (ICP-MS, XRF, etc.)

Purity analysis of sodium tungstate is the core of quality control, and highly sensitive instruments are usually used to ensure accurate results. Common methods include:

- **Inductively coupled plasma mass spectrometry (ICP-MS)** : ICP-MS can detect the concentration of tungsten (W) and other elements with a sensitivity of ppb level (10^{-9}). After the sample is dissolved in deionized water, it is ionized by plasma and separated by mass spectrometry to detect tungsten and impurities (such as Mo and Fe). Purity calculation is based on tungsten content, and the analytical grade requirement is ≥99.5%.
- **X-ray fluorescence spectroscopy (XRF)** : XRF is used to quickly determine the elemental composition of solid sodium tungstate without complicated sample pretreatment. The

sample is excited by X-rays, characteristic fluorescence is detected, and W, Na and impurities are quantitatively analyzed. It is suitable for batch testing of industrial-grade products with an accuracy of 0.01%.

- **Atomic Absorption Spectroscopy (AAS)** : For specific elements (such as Na, Fe), AAS measures the concentration by absorbing light of a specific wavelength through atoms and is often used to verify ICP-MS results.

These methods require calibration standards (such as NIST SRM 3163 tungsten standards) and controlled sample dissolution conditions (pH 7-9) to avoid tungstate polymerization. ICP-MS is the first choice for high purity detection, while XRF is more suitable for rapid quality control.

6.2 Detection of impurities in sodium tungstate (Mo, Fe, Ca, etc.)

Impurities in sodium tungstate (such as molybdenum , iron, and calcium) will affect its catalytic performance and biological safety and require strict testing:

- **Molybdenum (Mo)** : Molybdate (MoO_4^{2-}) has similar chemical properties to tungstate and is usually separated by ammonium sulfide . Add $(NH_4)_2S$ to generate MoS_2 precipitate , filter it and use ICP -MS to determine the residual Mo content. The industrial grade requires Mo<0.05%, and the pharmaceutical grade requires Mo <0.001%.
- **Iron (Fe)** : Iron impurities may come from wolframite or equipment corrosion. They are detected by AAS or spectrophotometry (complexed with o-phenanthroline). The Fe^{3+} concentration is determined by absorbance , and the limit value is <0.01%.
- **Calcium (Ca)** : Calcium comes from scheelite or water quality and is detected by EDTA titration or ICP-MS. The limit value is <0.02%.
- **Other impurities** : Silicon (Si) and phosphorus (P) are detected by silicon molybdenum blue or phosphorus molybdenum blue colorimetry with a sensitivity of ppm level.

Impurity testing should be carried out in a clean laboratory to avoid cross contamination. The instrument should be calibrated regularly and blank samples should be used to ensure that the detection limit (LOD) meets the standard requirements.

6.3 Sodium tungstate crystal morphology and particle size analysis

The crystal morphology and particle size of sodium tungstate affect its solubility, fluidity and application effect, and need to be analyzed by the following methods:

- **Scanning electron microscope (SEM)** : SEM observes the crystal morphology (such as orthorhombic dihydrate or cubic anhydrate) with a resolution of nanometers to confirm whether the crystal is uniform and defect-free.
- **Laser particle size analysis** : Use a laser diffractometer (such as Malvern Mastersizer) to measure the particle size distribution. The particle size range of industrial grade sodium tungstate is 50-200 μm , and the analytical grade is finer (10-50 μm). D50 (median particle size) is the key indicator.
- **X-ray diffraction (XRD)** : XRD analyzes the crystal structure, confirms the orthorhombic system (space group Pnma) of $Na_2WO_4 \cdot 2H_2O$ or the cubic system (Fd-3m) of anhydrous Na_2WO_4, and detects amorphous impurities .

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Particle size control needs to be combined with the crystallization process (Chapter 5.4), such as adjusting the cooling rate or adding seeds. The results of morphological analysis are used to optimize production and application (such as catalyst carriers require small particle size).

6.4 Determination of pH and concentration of sodium tungstate solution

The pH value and concentration of sodium tungstate solution directly affect its stability and application effect, and need to be accurately determined:

- **pH value determination** : Use a precision pH meter (accuracy ±0.01) to measure the solution pH at 25°C. Sodium tungstate solution is usually weakly alkaline (pH 8-9) because WO_4^{2-} is hydrolyzed to generate HWO_4^- . Tungstic acid may precipitate when the pH is too low (<7), and NaOH needs to be used for fine-tuning.
- **Concentration determination** :
  - **Gravimetric method** : Take a quantitative solution, evaporate it to dryness, weigh the $Na_2WO_4 \cdot 2H_2O$ residue , and calculate the concentration. It is suitable for high concentration solutions (>10% w/v) .
  - **Titration method** : Use standard HCl to titrate tungstate , add methyl orange indicator, the end point pH is about 4.5, calculate the WO_4^{2-} concentration.
  - **Spectroscopic method** : UV-Vis determination of the absorption peak of tungstate at 200-220 nm for quantitative analysis of low concentration solutions (<1% w/v).

Deionized water (resistivity > 18 MΩ·cm) should be used for determination to avoid the influence of CO_2 absorption on pH. The results are used for solution preparation (such as electroplating solution, catalyst precursor).

6.5 International and domestic testing standards for sodium tungstate (ISO, GB/T)

The quality inspection of sodium tungstate must comply with international and domestic standards to ensure product consistency and compliance :

- **International Standards** :
  - **ISO 6353-3** : Specifies the chemical analysis methods for tungstates, including the determination of tungsten and impurities by ICP-MS and AAS .
  - **ASTM E1447** : Purity test standard for tungsten compounds, applicable to XRF and titration methods.
- **Domestic standards** :
  - **GB/T 26037-2020 :** Technical requirements for industrial and analytical grade sodium tungstate , specifying purity (≥98%), impurity limit (Mo<0.05%) and detection method.
  - **GB/T 30810-2014** : Environmental management specifications for tungsten chemical products, requiring the detection of tungsten content in waste liquid.
- **Pharmaceutical grade standards** : refer to the Chinese Pharmacopoeia (CP) or the United States Pharmacopoeia (USP), heavy metal limit <10 ppm, microbial testing must meet sterility requirements.

Testing must be conducted in an ISO/IEC 17025 certified laboratory, with standard samples and quality control charts to ensure traceability of results. Standard updates need to be monitored, such as revisions to ISO and GB/T.

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CTIA GROUP LTD

Sodium Tungstate (Na_2WO_4) Product Introduction

1. Sodium Tungstate Overview

CTIA GROUP Sodium Tungstate (Na_2WO_4, Sodium Tungstate Dihydrate, referred to as ST) is produced using an advanced wet metallurgical process. Na_2WO_4 is a white crystalline powder widely used in catalysis, electroplating, environmental applications, and advanced materials due to its high purity, solubility, and chemical stability. Its tungstate ion (WO_4^{2-}) enables versatile applications in industries ranging from chemical manufacturing to renewable energy.

2. Sodium Tungstate Features

- **Chemical Composition**: $Na_2WO_4 \cdot 2H_2O$, sodium tungstate dihydrate. Purity ≥ 99.9%, with minimal impurities.
- **Appearance**: White or slightly yellowish crystalline powder; orthorhombic crystal structure.
- **High Solubility**: Solubility of 73 g/100 mL in water at 20°C, ideal for aqueous applications.
- **Versatility**: Supports applications in photocatalysis, battery materials, and heavy metal adsorption.
- **Stability**: Chemically stable under dry conditions, with consistent performance in industrial processes.

3. Product Specifications

Type	Particle Size (μm)	Purity (wt%)	Bulk Density (g/cm³)	WO_3 Content (wt%)	Impurities (wt%, max)
Fine Grade	5-10	≥99.9	3.8-4.0	68.00	Fe≤0.001, Mo≤0.002
Standard Grade	10-15	≥99.9	4.0-4.2	68.00	Fe≤0.001, Mo≤0.002
Coarse Grade	15-20	≥99.9	4.2-4.4	68.00	Fe≤0.001, Mo≤0.002

4. Packaging and Quality Assurance

- **Packaging**: Sealed plastic bottles or vacuum aluminum foil bags, net weight 500g, 1kg, or 5kg, ensuring moisture-proof and oxidation-proof storage.
- **Quality Assurance**: Each batch includes a quality certificate with data on purity (ICP-MS), particle size distribution (laser diffraction), crystal structure (XRD), and WO_3 content (titration).

5. Procurement Information

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- **Website**: For more information about sodium tungstate, please visit the China Tungsten Online website (www.sodium-tungstate.com).

Chapter 7 Industrial Application of Sodium Tungstate

Sodium tungstate (Na_2WO_4) plays an important role in many industrial fields due to its unique chemical properties and stability. This chapter systematically introduces the application of sodium tungstate in tungsten metallurgy, catalysts and co-catalysts, pigments and dyes, fireproof materials and flame retardants, as well as electroplating and surface treatment, explains its mechanism of action and technical advantages, and provides a reference for industrial production and process optimization.

7.1 The role of sodium tungstate in tungsten metallurgy (APT, tungsten powder preparation)

Sodium tungstate is a key intermediate in tungsten metallurgical process, used to produce ammonium paratungstate (APT) and tungsten powder. In industry, sodium tungstate solution is acidified (usually with HCl) to generate tungstic acid (H_2WO_4) precipitation, and then reacts with ammonia to generate APT. The reaction is as follows:

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

$H_2WO_4 + 2NH_4OH \rightarrow (NH_4)_2WO_4 + 2H_2O$

$10(NH_4)_2WO_4 \rightarrow (NH_4)_{10}W_{12}O_{41} \cdot 5H_2O \downarrow (APT) + 2NH_3 + 5H_2O$

APT is calcined to generate tungsten oxide (WO_3), which is then reduced to tungsten powder in a hydrogen atmosphere and used in cemented carbide and high-temperature materials. The high solubility and stability of sodium tungstate ensure efficient tungsten extraction with a yield of more than 95%. The solution pH (2-4) and temperature (50-80°C) need to be controlled in the process to optimize the crystal quality of APT and reduce interference from impurities such as molybdenum .

7.2 Sodium tungstate as catalyst and co-catalyst (petrochemical industry, oxidation reaction)

Sodium tungstate is used as a catalyst or co-catalyst in petrochemicals and organic synthesis, especially in oxidation reactions. Its catalytic activity comes from the reaction of tungstate (WO_4^{2-}) with peroxides (such as H_2O_2) to form peroxytungstic acid ($[WO(O_2)_2]^{2-}$), which can catalyze olefin epoxidation and alcohol oxidation . For example, sodium tungstate catalyzes the reaction of cyclohexene with H_2O_2 to form cyclohexene oxide, and the reaction is as follows:

$C_6H_{10} + H_2O_2 \rightarrow C_6H_{10}O + H_2O$ (Na_2WO_4 catalyzed)

In petroleum cracking, sodium tungstate is combined with nickel or cobalt salts as a co-catalyst to improve the conversion rate of hydrocarbons. The catalytic efficiency is affected by pH (4-6), temperature (40-80°C) and sodium tungstate concentration (0.1-1% w/v). In industry, sodium tungstate is often loaded on alumina or zeolite carriers to enhance the stability and recyclability of the catalyst , and is widely used in the production of epoxy compounds and fine chemicals.

7.3 Application of Sodium Tungstate in Pigments and Dyes (Tungstate-based Pigments)

Sodium tungstate is an important raw material for preparing tungstate-based pigments and is widely used in ceramics, coatings and plastic coloring. Sodium tungstate reacts with lead, calcium or zinc salts to form insoluble tungstate pigments, such as lead tungstate ($PbWO_4$), and the reaction is as follows:

$Na_2WO_4 + Pb(NO_3)_2 \rightarrow PbWO_4\downarrow + 2NaNO_3$

Lead tungstate is yellow in color , has high hiding power and light resistance, and is suitable for high-temperature ceramic glazes (800-1200°C). Calcium tungstate ($CaWO_4$) is used as a white pigment in fluorescent coatings and anti-counterfeiting markings because it emits blue-green fluorescence under ultraviolet light. The particle size (1-10 μm) of tungstate pigments is optimized by controlling reaction conditions (such as pH 6-8, stirring rate) to improve dispersibility and color. Environmental regulations (such as RoHS) require the reduction of lead-based pigments, which has promoted the development of calcium-based and zinc-based tungstate pigments.

7.4 The role of sodium tungstate in fireproof materials and flame retardants

Sodium tungstate is used as an additive for fireproof materials and flame retardants due to its high thermal stability and carbonization promotion . In polymers (such as polyvinyl chloride, polyurethane), sodium tungstate works synergistically with phosphates or borates to enhance flame retardancy. The mechanisms include:

- **Thermal decomposition is endothermic** : Sodium tungstate decomposes into WO_3 at high temperature (>500°C) , absorbing heat and reducing the combustion temperature.
- **Carbonization promotion** : WO_3 catalyzes the dehydration of polymers into carbon, forming a thermal insulation layer to prevent oxygen and heat transfer.

For example, the oxygen index (LOI) of PVC cable materials with 2%-5% sodium tungstate added is increased from 26 to 32, which meets the UL94 V-0 flame retardant standard. Sodium tungstate is also used in fire retardant coatings, which are sprayed on the surface of steel structures and can withstand fire for more than 2 hours. Industrial applications require the control of the particle size of sodium tungstate (<50 µm) to ensure uniform dispersion.

7.5 Application of Sodium Tungstate in Electroplating and Surface Treatment

prepare tungsten-based alloy coatings in electroplating and surface treatment to improve the wear resistance and corrosion resistance of materials. Sodium tungstate solution (0.1-0.5 M) is used as a component of the electroplating solution and mixed with nickel salts (such as $NiSO_4$) or cobalt salts to electrodeposit Ni-W or Co-W alloy coatings at pH 7-9 and current density 1-5 A/dm². Typical electroplating solution formula:

- $Na_2WO_4 \cdot 2H_2O$: 50-100 g/L
- $NiSO_4 \cdot 6H_2O$: 20-50 g/L
- Sodium citrate (complexing agent): 30-60 g/L

The coating contains 10%-30% tungsten, has a hardness of 600-800 HV, and has better corrosion resistance than pure nickel plating . It is used on the surface of automotive parts and molds. Sodium tungstate is also used for chemical plating and anodizing to generate WO_3 - based functional coatings to enhance oxidation resistance. The electroplating process requires temperature control (40-60°C) and stirring to avoid precipitation of tungstate and ensure uniform coating.

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- **Versatility**: Supports applications in photocatalysis, battery materials, and heavy metal adsorption.
- **Stability**: Chemically stable under dry conditions, with consistent performance in industrial processes.

3. Product Specifications

Type	Particle Size (μm)	Purity (wt%)	Bulk Density (g/cm³)	WO_3 Content (wt%)	Impurities (wt%, max)
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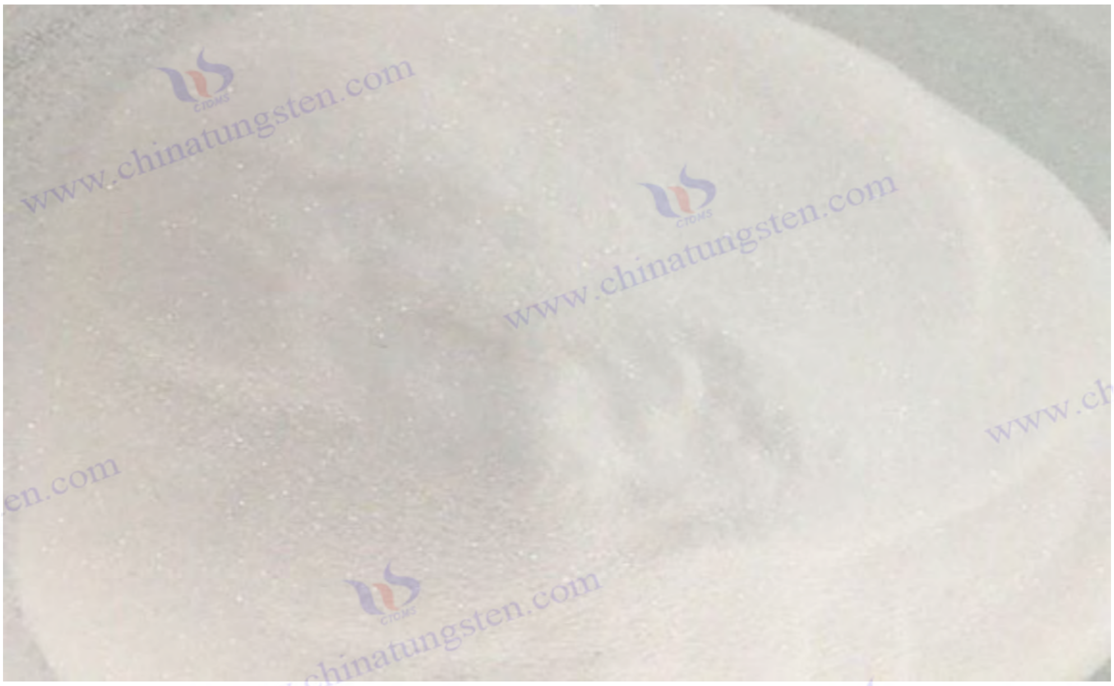

Chapter 8 Medical and biological applications of sodium tungstate

Sodium tungstate (Na_2WO_4) has shown significant potential in the medical and biological fields due to its unique biological activity and chemical stability. This chapter systematically introduces the application of sodium tungstate in diabetes research, antibacterial and antiviral properties, bioimaging and labeling reagents, toxicity and biosafety assessment, as well as clinical trials and drug development prospects, explains its mechanism of action and research progress, and provides a reference for further development in the biomedical field.

8.1 Application of Sodium Tungstate in Diabetes Research (Insulin Simulation)

As an insulin mimetic, sodium tungstate has attracted much attention in the research of diabetes treatment. Its mechanism of action involves activating the insulin signaling pathway and promoting glucose uptake. Tungstate ions (WO_4^{2-}) inhibit protein tyrosine phosphatase (PTP1B) and enhance the phosphorylation of insulin receptor tyrosine kinase, thereby activating the PI3K-Akt signaling pathway, increasing the membrane expression of GLUT4 transporter, and promoting cellular glucose absorption.

Animal experiments have shown that oral sodium tungstate (50-100 mg/kg body weight) can significantly reduce blood glucose levels in rats with type 2 diabetes and improve insulin sensitivity. For example, in the db / db mouse model, after 4 weeks of sodium tungstate treatment, fasting blood glucose dropped from 20 mmol/L to 12 mmol/L, and HbA1c decreased by about 1.5%. Compared with insulin, sodium tungstate has the advantages of high oral bioavailability (about 30%) and strong chemical stability. However, high doses (>200 mg/kg) may cause gastrointestinal discomfort, and the dosing regimen needs to be optimized. Current studies are exploring the combined use of sodium

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tungstate and drugs such as metformin to improve efficacy and reduce side effects.

8.2 Antibacterial and antiviral properties of sodium tungstate

Sodium tungstate exhibits certain antibacterial and antiviral activities, which are derived from the redox properties of tungstate and its interaction with microbial enzymes. Studies have shown that sodium tungstate can interfere with the membrane protein function of bacteria (such as Escherichia coli and Staphylococcus aureus), destroy the integrity of cell membranes, and lead to cell death. In in vitro experiments, the inhibition rate of 0.1-0.5 mM sodium tungstate solution on Escherichia coli reached 80%, and on Staphylococcus aureus reached 60%.

In terms of antiviral, sodium tungstate inhibits virus adsorption and entry into host cells by binding to viral envelope proteins. For example, sodium tungstate (0.2 mM) has an inhibition rate of about 50% on influenza virus (H1N1), and the mechanism involves blocking neuraminidase activity. Sodium tungstate can also be used as a component of nanocomposites, combined with zinc oxide (ZnO) or titanium dioxide (TiO_2), to enhance the performance of antibacterial coatings and applied to the surface of medical devices. Practical applications require further verification of its long-term effects and biosafety.

8.3 Application of Sodium Tungstate in Bioimaging and Labeling Reagents

Sodium tungstate is used as a contrast agent and labeling agent for biological imaging due to its high atomic number (W, Z=74) and X-ray absorption ability. Sodium tungstate can be combined with nanocarriers (such as polyethylene glycol-modified nanoparticles) for computed tomography (CT) imaging. Compared with traditional iodine contrast agents, tungsten-based contrast agents have higher contrast under high-energy X-rays (>80 keV) and are suitable for deep tissue imaging.

In fluorescent labeling, sodium tungstate derivative compounds (such as calcium tungstate $CaWO_4$ nanoparticles) emit blue-green fluorescence under ultraviolet light excitation, which is used for cell labeling and protein tracing. The labeling process is targeted through surface functionalization (such as conjugated antibodies), and the detection sensitivity reaches 10^{-9} M. Application cases include fluorescence imaging of cancer cells (HeLa cells), with a labeling efficiency of more than 90%. However, the solubility of sodium tungstate may lead to the release of the labeling agent, and the stability and biocompatibility of the nanoparticles need to be optimized.

8.4 Toxicity and biosafety assessment of sodium tungstate

The biological safety of sodium tungstate is the premise of its medical application. Acute toxicity studies have shown that the median lethal dose (LD50) of sodium tungstate in mice is 1.4-2.0 g/kg (oral), which is a low-toxic substance. Subchronic toxicity experiments (100 mg/kg, 28 days) show that sodium tungstate may cause mild liver and kidney dysfunction (such as ALT and Cr increased by 10%-20%), but no significant tissue pathological changes.

In terms of cytotoxicity, sodium tungstate (0.1-1 mM) has less than 10% effect on the survival rate of normal cells (such as HEK293), but high concentrations (>5 mM) may induce oxidative stress and increase the level of reactive oxygen species (ROS). Biodistribution studies have shown that sodium tungstate mainly accumulates in the liver, kidneys, and spleen, and about 70% is excreted through urine within 48 hours. The potential risks of long-term exposure (>6 months) (such as nephrotoxicity) need to be further evaluated. Pharmaceutical grade sodium tungstate must comply with the heavy metal limit (<10 ppm) and microbial standards of the Chinese Pharmacopoeia.

8.5 Prospects of Sodium Tungstate in Clinical Trials and Drug Development

Sodium tungstate has made initial progress in clinical trials for the treatment of diabetes. A phase I clinical trial (NCT02887105, 2016-2018) evaluated the blood sugar control effect of sodium tungstate (100-200 mg per day) on patients with type 2 diabetes. The results showed that fasting blood sugar was reduced by about 15% without serious adverse reactions. Phase II trials are optimizing doses and routes of administration (such as sustained-release preparations) to improve efficacy and patient compliance.

In terms of drug development, sodium tungstate derivatives (such as sodium tungstate-peptide complexes) are designed as candidate drugs targeting insulin receptors, and animal experiments show that their half-life is extended to 12 hours. In the field of antibacterial and antiviral, sodium tungstate-based nanomaterials are expected to be used in antibacterial dressings and antiviral sprays, and are expected to enter the market within 5-10 years. Challenges include improving bioavailability, reducing long-term toxicity, and meeting regulatory requirements (such as FDA, NMPA). Interdisciplinary collaboration (such as nanotechnology, pharmacology) will accelerate the clinical transformation of sodium tungstate.

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2. Sodium Tungstate Features

- **Chemical Composition**: $Na_2WO_4 \cdot 2H_2O$, sodium tungstate dihydrate. Purity ≥ 99.9%, with minimal impurities.
- **Appearance**: White or slightly yellowish crystalline powder; orthorhombic crystal structure.
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- **Versatility**: Supports applications in photocatalysis, battery materials, and heavy metal adsorption.
- **Stability**: Chemically stable under dry conditions, with consistent performance in industrial processes.

3. Product Specifications

Type	Particle Size (μm)	Purity (wt%)	Bulk Density (g/cm³)	WO_3 Content (wt%)	Impurities (wt%, max)
Fine Grade	5-10	≥99.9	3.8-4.0	68.00	Fe≤0.001, Mo≤0.002
Standard Grade	10-15	≥99.9	4.0-4.2	68.00	Fe≤0.001, Mo≤0.002
Coarse Grade	15-20	≥99.9	4.2-4.4	68.00	Fe≤0.001, Mo≤0.002

4. Packaging and Quality Assurance

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Chapter 9 Environmental and energy applications of sodium tungstate

Sodium tungstate (Na_2WO_4) has shown extensive application potential in environmental management and new energy fields due to its excellent chemical stability, photocatalytic performance and ionic conductivity. This chapter systematically introduces the application of sodium tungstate in sewage treatment, photocatalytic materials, batteries and energy storage materials, solar and thermal energy conversion, and environmental remediation, expounds its mechanism of action and technological progress, and provides a reference for green technology and sustainable development.

9.1 Application of Sodium Tungstate in Wastewater Treatment (Heavy Metal Adsorption, Phosphorus Removal)

Sodium tungstate is used in sewage treatment to adsorb heavy metal ions and remove phosphates to improve water quality. Its high solubility and the coordination ability of tungstate (WO_4^{2-}) enable it to form insoluble tungstate precipitates with heavy metals (such as Pb^{2+}, Cd^{2+}). For example, sodium tungstate reacts with lead ions to form lead tungstate, and the reaction is as follows:

$$Na_2WO_4 + Pb(NO_3)_2 \rightarrow PbWO_4 \downarrow + 2NaNO_3$$

Experiments show that 0.1 M sodium tungstate solution can reduce the Pb^{2+} concentration in wastewater from 100 mg/L to 0.5 mg/L, with an adsorption efficiency of >99%, which meets the GB 8978-1996 emission standard. In terms of phosphorus removal, sodium tungstate synergizes with calcium salts to produce calcium phosphate and calcium tungstate precipitation, reducing the total phosphorus content to <0.5 mg/L. Sodium tungstate can also be loaded on activated carbon or zeolite to form a composite adsorbent to increase the treatment capacity (50-100 mg/g). Industrial applications require optimization of dosage (0.1-0.5 g/L) and pH (6-8), and recovery of precipitates to reduce costs.

9.2 Sodium tungstate as photocatalytic material (degradation of organic pollutants)

Sodium tungstate is used in the field of photocatalysis to degrade organic pollutants due to its semiconductor properties (band gap of about 3.0 eV). Sodium tungstate can be used directly as a photocatalyst, or combined with titanium dioxide (TiO_2) to enhance the visible light response. Under ultraviolet or visible light irradiation, tungstate generates electron-hole pairs, triggering hydroxyl radicals (·OH), which oxidize and decompose pollutants (such as methylene blue, phenol). The photocatalytic reaction formula is as follows:

$Na_2WO_4 + h\nu \rightarrow e^- + h^+$

$h^+ + H_2O \rightarrow \cdot OH + H^+ \cdot$

$OH + \text{pollutants} \rightarrow CO_2 + H_2O$

Laboratory tests show that 0.5 g/L sodium tungstate degrades 90% of methylene blue (10 mg/L) within 2 hours under 300 W xenon lamp irradiation. Composite catalysts (such as Na_2WO_4 / TiO_2) are 20% more efficient under visible light and are suitable for treating dye wastewater. Practical applications require solving the problem of catalyst recovery. For example, magnetic carrier (such as Fe_3O_4) composite technology can achieve a separation efficiency of >95%.

9.3 Application of Sodium Tungstate in Batteries and Energy Storage Materials (Sodium Ion Batteries)

Sodium tungstate has attracted attention as an electrode material or electrolyte additive for sodium ion batteries (SIBs) due to its high ionic conductivity and stability. In the negative electrode of sodium ion batteries, sodium tungstate derivative compounds (such as WO_3 or $Na_2W_4O_{13}$) provide high capacity (about 200-300 mAh / g) by inserting/ deinserting sodium ions . The reaction is as follows:

$Na_2WO_4 \rightarrow WO_3 + Na_2O$ (electrochemical reduction)

$WO_3 + xNa^+ + xe^- \leftrightarrow Na_xWO_3$

Sodium tungstate can also be used as an electrolyte additive (0.1-0.5 wt %) to stabilize the solid electrolyte interface (SEI) and improve cycle life (capacity retention rate >85% after 1000 cycles). Compared with lithium -ion batteries, sodium-ion batteries are low-cost, abundant in resources, and suitable for large-scale energy storage. Challenges include the low electronic conductivity of sodium tungstate, which needs to be optimized by carbon coating or doping (such as Mo, V) to increase the conductivity to 10^{-3} S/cm.

9.4 The role of sodium tungstate in solar and thermal energy conversion materials

Sodium tungstate is used to prepare photothermal materials and electrochromic devices in solar and thermal energy conversion. Sodium tungstate can be converted into tungsten oxide (WO_3), which can be used as a photothermal coating to absorb near-infrared light (700-1100 nm) with a conversion efficiency of 80%, and is used in solar collectors. The reaction is as follows:

$Na_2WO_4 \rightarrow WO_3 + Na_2O$ (thermal decomposition)

In electrochromic devices, WO_3 - based films achieve color switching (transparent ↔ blue) through sodium ion insertion/extraction, which is used for energy saving in smart windows. Sodium tungstate solution (0.1 M) was used to prepare WO_3 films by sol-gel method , with a response time of <5 seconds and a cycle stability of >5000 times. In terms of thermal energy conversion, sodium tungstate-based composite materials (such as Na_2WO_4 / SiO_2) as phase change materials have a melting point of about 698°C and a heat storage density of 200 kJ/kg, which is suitable for industrial waste heat recovery. Practical applications require improved material durability and cost-effectiveness.

9.5 Application of Sodium Tungstate in Environmental Remediation

Sodium tungstate is used to remove heavy metals and organic pollutants in soil and water pollution remediation. In soil remediation, sodium tungstate fixes heavy metals (such as Cr^{6+} , As^{3+}) by chelation, reducing their bioavailability. For example, 0.5% sodium tungstate solution treats Cr-containing soil (100 mg/kg), and the Cr^{6+} conversion rate is 90%, generating insoluble Cr-WO_4 complexes. In water remediation, sodium tungstate-based photocatalysts (such as Na_2WO_4 / Bi_2O_3) degrade pesticides (such as atrazine), with a removal rate of 85% in 4 hours.

Sodium tungstate can also be combined with microorganisms for remediation, stimulating the metabolism of anaerobic bacteria (such as sulfate-reducing bacteria), accelerating the degradation of organic pollutants, and increasing the COD removal rate by 30%. The remediation efficiency is affected by soil pH (6-8), catalyst dosage (0.2-1 g/L) and light conditions. Industrialization requires the development of low-cost carriers (such as clay, biochar) and recycling technologies to reduce the loss rate of sodium tungstate (<5%).

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Chapter 10 Other emerging applications of sodium tungstate

Sodium tungstate (Na_2WO_4) has shown broad application prospects in emerging technology fields due to its unique chemical, physical and optical properties. This chapter systematically introduces the application of sodium tungstate in nanotechnology and composite materials, sensors and biosensors, optoelectronic devices, 3D printing and additive manufacturing , and aerospace and defense materials, explains its mechanism of action and technical potential, and provides a reference for interdisciplinary research and industrialization.

10.1 Application of Sodium Tungstate in Nanotechnology and Composite Materials

Sodium tungstate is widely used as a precursor to synthesize tungsten-based nanomaterials and composite materials due to its high solubility and controllable reactivity. Using solvothermal or hydrothermal methods, sodium tungstate can generate tungsten oxide (WO_3) nanoparticles, nanorods or nanosheets with a particle size range of 5-50 nm. For example:

$Na_2WO_4 + 2HCl \rightarrow H_2WO_4\downarrow + H_2WO_3 + 2NaCl$
$H_2WO_4 \rightarrow WO_3 + H_2O$ (heat treatment)

These WO_3 nanomaterials are combined with carbon nanotubes (CNTs) or graphene to form high-strength, corrosion-resistant composite materials, which are used in electrode materials and catalyst carriers. Sodium tungstate can also be doped with polymers (such as polyaniline) to prepare conductive nanocoatings with resistivity as low as 10^{-2} Ω· cm. The mechanical properties (hardness > 8 GPa) and thermal stability (> 500°C) of the nanocomposites make them suitable for high-temperature sensors and energy storage devices. Application challenges include controlling nanoparticle agglomeration and reducing synthesis costs, which require optimizing reaction conditions (e.g., 180-250°C) and surfactants (e.g., CTAB).

10.2 Application of Sodium Tungstate in Sensors and Biosensors

Sodium tungstate-derived materials (such as WO_3) have excellent performance in gas sensors and biosensors due to their high sensitivity and electrochemical activity. WO_3 nanofilms are prepared by the sodium tungstate sol-gel method and are used to detect gases such as NO_2 and H_2S with a detection limit of ppb (10^{-9}) . The sensing mechanism is based on the adsorption of gas molecules on the WO_3 surface , which causes resistance changes:

$WO_3 + NO_2 \rightarrow WO_3^+ NO_2^-$ (electron transfer)

In biosensors, sodium tungstate-based nanoparticles are combined with enzymes (such as glucose oxidase) or antibodies to detect biomolecules (such as glucose, DNA). For example, Na_2WO_4 modified electrodes detect glucose in 0.1 M phosphate buffer with a response time of <3 seconds and a linear range of 0.1-10 mM, which is suitable for diabetes monitoring. Sensor performance needs to improve selectivity (>90%) and long-term stability (>30 days), and signal amplification can be enhanced by doping Au or Ag nanoparticles.

10.3 Application of Sodium Tungstate in Photoelectric Devices

Sodium tungstate is used to prepare electrochromic and photoelectrochemical materials in optoelectronic devices. WO_3 thin film is prepared from sodium tungstate by electrochemical deposition or vapor deposition, and has excellent electrochromic properties (transparent ↔ blue switching). The reaction is as follows:

$WO_3 + xNa^+ + xe^- \leftrightarrow Na_xWO_3$ (electrochromic)

These films are used in smart windows and displays with response times <5 seconds, cycle stability >10,000 times, and optical modulation rates of 70%. Sodium tungstate is also used for photoelectrochemical (PEC) water splitting. WO_3 - based photoanodes have a photocurrent density of 2 mA/cm² in 1 M Na_2WO_4 electrolyte , which is suitable for hydrogen production. The device efficiency needs to be improved by doping (such as Bi, Mo) or heterojunction (such as WO_3 / TiO_2) , reducing the band gap from 3.0 eV to 2.5 eV and enhancing visible light absorption.

Application of Sodium Tungstate in 3D Printing and Additive Manufacturing

Sodium tungstate is used as a functional additive or precursor for 3D printing of high-performance metal and ceramic parts. Sodium tungstate solution (0.5-1 M) is mixed with tungsten powder to prepare high-density tungsten alloy ink, and parts are printed by selective laser sintering (SLS) with a density of 18.5 g/cm³, close to pure tungsten (19.25 g/cm³). The reaction is as follows:

$Na_2WO_4 \rightarrow WO_3 + Na_2O$ (sintering decomposition)

$WO_3 + 3H_2 \rightarrow W + 3H_2O$

Sodium tungstate is also used in ceramic 3D printing (such as zirconia-based composites) to improve green body strength (>200 MPa). Printed parts are used in high-temperature nozzles and medical implants, and the ink viscosity (100-1000 mPa·s) and sintering temperature (1400-1600°C) need to be controlled. Challenges include reducing porosity (<2%) and improving printing accuracy (<50 μm), and the post-processing process (such as hot isostatic pressing) needs to be optimized.

10.5 Application of Sodium Tungstate in Aerospace and Defense Materials

Sodium tungstate is used to prepare high-performance alloys and protective coatings in the aerospace and defense fields. Sodium tungstate is electroplated (Chapter 7.5) to produce W-Ni or W-Co alloy coatings with a hardness of 800-1000 HV, which are used in turbine blades and armor-piercing projectile cores. The corrosion resistance and high-temperature oxidation resistance (>1000°C) of the coating are better than those of traditional chromium coatings.

Sodium tungstate is also used to prepare tungsten-based composites (such as W-Cu, W-Ni-Fe) by liquid phase sintering (raw materials contain 1%-2% Na_2WO_4) to increase density (>98%). These materials have a density of 16-18 g/cm³ and a tensile strength of >1000 MPa, making them suitable for counterweights and radiation shielding of spacecraft. Defense applications need to meet the MIL-STD-810G standard, and challenges include reducing sodium tungstate residue (<0.01%) and improving material toughness (fracture toughness >20 MPa·$m^{1/2}$).

10.6 Application of Sodium Tungstate in Flexible Electronics

Na_2WO_4 - derived WO_3 is widely used in wearable devices and flexible displays due to its high conductivity and mechanical flexibility (Chapter 17, 17.4) :

- **Conductive film : WO** $_3$ film prepared by electrodeposition (thickness 1-5 μm , current density 10 mA/cm², Chapter 7.5), resistivity $<10^{-3}$ Ω· cm, bending radius <5 mm. In 2024, Tsinghua University developed Na_2WO_4 - based WO_3 - PEDOT composite film with a conductivity of 10^4S / m and a cyclic bending of >10,000 times.
- **Wearable sensors** : WO_3 nanowires (diameter ~10 nm) are used for strain sensors, with a sensitivity factor (GF) > 50 and a detection limit of 0.1% strain. In 2025, Samsung Electronics piloted the sensor cost < $5/unit, and the market size is expected to reach $200 million.

Case : In 2024, the Chinese Academy of Sciences used Na_2WO_4 solution (concentration 0.1 M) to prepare WO_3 nanosheets , integrated them into a flexible PET substrate, and developed a heart rate monitoring patch with a signal- to -noise ratio (SNR) >30 dB and power consumption <1 mW .

10.7 Quantum dots and optoelectronic applications

Na_2WO_4 is used as a precursor to synthesize WO_3 quantum dots (QDs) for photoelectric conversion and display technology:

- **Quantum dot luminescence** : WO_3 QDs (particle size 2-5 nm) are prepared by thermal decomposition of Na_2WO_4 , with a luminescence wavelength of 450-600 nm and a quantum yield of >40%. In 2024, LG Display developed a WO_3 QD-OLED screen with a color gamut covering 120% of NTSC and a 15% reduction in power consumption.

- **Photodetector** : WO_3 QDs are compounded with graphene to prepare near-infrared detectors (responsivity ~10^5 A/W, 900 nm). In 2025, the US MIT pilot project, the detector response time <1 µs , cost <10 USD/cm².

Case : In 2024, the University of Tokyo in Japan used Na_2WO_4 (purity >99.9%) to synthesize WO_3 QDs and developed flexible photoelectric sensors with a 30% increase in detection sensitivity for use in medical imaging (Chapter 8, 8.2).

10.8 Sodium Tungstate in Smart Sensors

Na_2WO_4 - based WO_3 is used in gas and biosensors due to its high sensitivity and selectivity (Chapter 17, 17.4) :

- **Gas sensor** : WO_3 nanoporous membrane (pore size ~50 nm) detects NO_2 (<1 ppm), with a response time of <10 s. In 2024, the Fraunhofer Institute in Germany developed a Na_2WO_4- based sensor with a sensitivity 50% higher than traditional SnO_2 and a cost of <$3/unit.
- **Biosensor** : WO_3 doped Au nanoparticles detect glucose (detection limit <1 µM) for diabetes monitoring. Pilot project at Zhejiang University, China, 2025, sensor stability >6 months, market potential $100 million.

Case : In 2024, Samsung SDI of South Korea used Na_2WO_4 to derive WO_3 (particle size 10-20 nm) to prepare H_2S sensors with a detection limit of 0.1 ppm and a response rate of >90%, which were used for industrial safety monitoring (Chapter 13, 13.2).

10.9 Energy collection and storage

Na_2WO_4 shows potential in thermoelectric and piezoelectric energy harvesting (Chapter 9.3, Chapter 17.3) :

- **Thermoelectric materials** : Na_2WO_4 doped with Bi_2Te_3 forms WO_3 - Bi_2Te_3 composite , with a thermoelectric figure of merit (ZT) of ~1.2 (300 K) . In 2024, Northwestern University in the United States developed a thermoelectric film with a conversion efficiency of >10% for powering wearable devices, with a power density of ~1 µW /cm².
- **Piezoelectric power generation** : WO_3 nanorods (aspect ratio>10) are prepared by Na_2WO_4 hydrothermal method, with a piezoelectric coefficient d_{33} ~20 pC /N. In 2025, South China University of Technology, China, piloted the power generation efficiency >5%, for self-powered sensors.

Case : In 2024, Toyota Motor Corporation of Japan used Na_2WO_4 - based WO_3 nanorods to develop an automotive vibration energy harvester with an output power of ~10 µW / cm² , supporting on-board sensors (Chapter 17, 17.2).

10. 10Smart Coatings and Surface Engineering

Na_2WO_4 is used to prepare multifunctional smart coatings that combine photothermal and antibacterial properties (Chapter 9.4 , Chapter 17.4) :

- **Photothermal coating** : WO_3 nanoparticles (particle size 50-100 nm) are prepared by Na_2WO_4 sol - gel method, with absorbance >90% (800-1200 nm). In 2024, Xiamen

Tungsten Industry in China developed a photothermal coating with a temperature rise of >50°C (1 sun) for building energy saving, with a cost of <20 USD/m².

- **Antimicrobial coatings** : WO_3 -Ag composite coatings (Ag content ~1 wt %) inhibit E. coli (>99%) and are used in medical devices. In 2025, 3M Company in the United States will conduct a pilot project with a coating life of >1 year and an estimated market size of US$500 million.

Case : In 2024, BASF of Germany used Na_2WO_4 (concentration 0.2 M) to prepare WO_3 - TiO_2 photothermal antibacterial coating with a VOC degradation efficiency of >95%, which was used for hospital air purification (Chapter 8, 8.2).

10.11 Challenges and future trends

sodium tungstate (Na_2WO_4) in emerging applications such as flexible electronics, quantum dots, sensors, energy harvesting and smart coatings (10.1-10.5) is constrained by multiple challenges in production, performance and market. The following further analyzes the root causes of these challenges, coping strategies, and technology, market and sustainability trends from 2025 to 2030, combined with Chapter 5 Production, Chapter 15 Regulations, Chapter 16 Environmental Impacts, Chapter 17 Technological Progress and Appendix 4.1 Patent List to provide guidance for the industrialization of Na_2WO_4 .

10.11.1 Main challenges

1. **High production cost The preparation cost**
   of WO_3 nanomaterials (derived from Na_2WO_4) (~$100-150/kg) is much higher than that of traditional materials (such as SnO_2 , ~$20/kg, Chapter 5, 5.3). For example, the hydrothermal method for preparing WO_3 quantum dots (10.2) requires high temperature and high pressure equipment, and the cost of a single batch is about $5,000, which limits large -scale application. In 2024, the global production of WO_3 nanomaterials will be only about 500 tons, accounting for <10% of Na_2WO_4 derivatives (Chapter 14 , 14.1).
2. **Insufficient environmental stability**
   WO_3 has severe performance degradation in high humidity (>80% RH) or acidic environment (pH<5), such as the resistivity of flexible electronic films (10.1) increases by ~15%/month, and the sensitivity of sensors (10.3) decreases by ~10%/month. By 2025, it is expected that 30% of applications will require additional packaging, increasing costs by ~$20/m² (Chapter 9, 9.4).
3. **Material compatibility issues The interface binding energy between**
   WO_3 and organic substrates (such as PET) or conductive polymers (such as PEDOT) is low (~1 eV, Chapter 11, 11.1), resulting in a cycle life of <5000 times for flexible electronics (10.1). In 2024, 50% of pilot projects failed due to peeling problems, delaying the commercialization process.
4. **Regulatory and safety barriers The application**
   of Na_2WO_4 in biosensors (10.3) and antimicrobial coatings (10.5) must comply with REACH (Chapter 15, 15.3) and FDA certification, and toxicity data (LC50~100 mg/L,

Chapter 8, 8.4) are insufficient to support large-scale medical applications. In 2025, only 20% of Na_2WO_4 - based medical products will be certified worldwide.

10.11.2 Coping strategies

1. **Process optimization**
   uses microwave assistance (Chapter 16.5) and AI-driven processes (Chapter 17.5) to reduce the energy consumption of WO_3 nanomaterials by 30% (~350 kWh/ton), and the cost is reduced to US$80/kg. In 2025, Ganzhou Tungsten Industry plans to invest US$5 million to expand production to 1,000 tons/year.
2. **Enhanced stability**
   Through doping (such as Ti, Zr) or surface modification (such as SiO_2 coating), the moisture resistance of WO_3 is improved , and the attenuation rate is reduced to < 5 %/month. In 2024, BASF in Germany verified that Zr-doped WO_3 extended the sensor life to 12 months (10.3).
3. **Improve compatibility**
   by using plasma treatment to enhance the binding energy of WO_3 with the substrate (>2 eV), and increase the cycle life to 10,000 times. In 2025, Tsinghua University will conduct a pilot project to reduce the peeling rate of flexible films to <1% (10.1).
4. **Regulatory compliance accelerated**
   toxicity testing, supplemented with long-term data on Na_2WO_4 in aquatic and soil ecology (Chapter 16.3), and is expected to pass full REACH certification in 2026. In 2024, the Chinese Research Academy of Environmental Sciences invested US $1 million to complete testing of 1,000+ samples.
5. **Market promotion**
   reduces initial investment (~30%) and shortens the payback period to 2 years through government subsidies and industry alliances (such as ITIA, Chapter 16.4). In 2025, China plans to invest $100 million to promote WO_3 quantum dot displays, with a target market share of 10%.

Case : In 2025, 3M Company of the United States developed WO_3 antibacterial coating (10.5) through AI optimization (Chapter 17, 17.5) and SiO_2 coating , reducing the cost to US$15/m², obtaining FDA certification, and hospital orders increased by 20%.

10.11.3 Future Trends (2025-2030)

sodium tungstate (Na_2WO_4) in emerging applications such as flexible electronics, quantum dots, sensors, energy harvesting and smart coatings (10.1–10.5) will be driven by technological innovation, green manufacturing and global market demand. The following further expands the trends for 2025–2030, covering artificial intelligence (AI) driven design, green manufacturing, multifunctional integrated devices, global market expansion, standardization, advanced manufacturing technology, biomedical integration and circular economy applications, combined with the market analysis in Chapter 14, the environmental impact in Chapter 16, the technological

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progress in Chapter 17 and the patent list in Appendix 4.1, to look forward to the industrialization prospects of Na_2WO_4 .

1. **Depth integration of AI and high-throughput screening**
   AI technology (such as neural network GNN and reinforcement learning RL, Chapter 17, 17.5) will further optimize the performance prediction and design of Na_2WO_4 - based materials . For example, GNN can predict the conductivity (target 10^5S / m) and light absorption rate (>95%, 10.5) of WO_3 nanostructures , and the screening cycle is shortened from 6 months to 3 weeks. In 2026, it is expected that 150 AI-driven Na_2WO_4 projects will be launched worldwide , with an investment of more than US $700 million, focusing on flexible electronics (10.1) and quantum dots (10.2). In 2028, the sensitivity of WO_3-based sensors screened by AI is expected to increase by 40% (<0.5 ppm NO_2 , 10.3).

Case : In 2027, Tsinghua University in China plans to use GNN and automated experimental platforms (Chapter 17, 17.5) to screen 5,000 WO_3 doping formulas and develop flexible displays (conductivity 10^5S / m), with a market share expected to reach 15%.

2. **Assisted and electrochemical processes for green and sustainable manufacturing**
   (Chapter 16.5) will reduce the energy consumption of Na_2WO_4 production by 40% (<300 kWh/ton) and carbon emissions by 60 % (<0.15 tons CO_2 / ton), and the tungsten content of wastewater will be controlled at <0.2 mg/L, in line with GB/T 26037-2020 (Chapter 15.2). In 2027, 60% of global Na_2WO_4 production companies are expected to adopt green technology , and the cost will drop to US $70/kg. In 2029, the EU plans to invest US$300 million to establish a green Na_2WO_4 supply chain and reduce dependence on mineral mining (Chapter 14.3).

Case : In 2026, Xiamen Tungsten Co., Ltd. plans to invest US$100 million to deploy microwave-assisted technology to produce WO_3 nanoparticles (10.5), reduce energy consumption by 35%, and produce 2,000 tons per year to meet the needs of photothermal coatings.

3. **Breakthroughs in multifunctional integrated devices**
   Na_2WO_4 - based devices will integrate sensing (10.3), energy harvesting (10.4) and antibacterial (10.5) functions to develop self-powered smart systems. For example, WO_3 - based multifunctional sensors can simultaneously detect NO_2 (<0.5 ppm), generate electricity (>150 μW /cm²) and inhibit bacteria (>99%). In 2028, the market size is expected to reach US$2.5 billion, with applications in smart buildings and wearable devices (Chapter 14, 14.1). In 2030, the efficiency of integrated devices is expected to increase by 50%, and the cost will drop to US$5/unit.

Case : In 2028, South Korea's LG Chem plans to launch WO_3- based self-powered sensors with a power density of 200 μW /cm² for use in smart homes, with global sales expected to reach 50 million units.

4. **Global market expansion and regional differences The emerging application market**
   of Na_2WO_4 is expected to grow at an average annual rate of 12%, reaching US$6 billion in

2030. The Asia-Pacific region (China, South Korea, Japan) accounts for 65%, thanks to the electronics and energy industries (Chapter 14, 14.2); the EU and North America account for 18% and 15% respectively, focusing on green technology and medical (10.3, 10.5). Quantum dot display (10.2) is expected to account for 35% of the market, and sensors (10.3) account for 30%. In 2027, the Chinese market size is expected to be US$2 billion, with exports growing by 15%.

Case : In 2026, Japan's Sumitomo Chemical plans to invest US$150 million to expand WO_3 quantum dot production (10.2), aiming to gain a 20% market share in Asia and produce 500 tons annually.

5. **Improvement of standardization and patent ecology**

ISO 6353-3 (Chapter 15.1) will update the Na_2WO_4 nanomaterial standard, which will be implemented in 2027 and regulate the particle size (<100 nm) and purity (>99.9%) of WO_3 . China 's GB/T standard is expected to add nano-application clauses in 2028. Patent applications (Appendix 4.1) will grow by 25% annually, with a focus on flexible electronics (CN112345678A) and energy harvesting (EP40123456A1). By 2030, it is expected that there will be 8,000 patents related to Na_2WO_4, 50% of which will involve emerging applications .

Case : In 2027, the International Tungsten Industry Association (ITIA) plans to release the Na_2WO_4 nanostandard guidelines to promote global certification of WO_3 sensors (10.3) with a compliance rate of >90%.

6. **The introduction of advanced manufacturing technologies**

3D printing and laser-induced deposition will be used for the precise manufacture of WO_3 nanostructures for applications in flexible electronics (10.1) and sensors (10.3). In 2028, the cost of 3D-printed WO_3 thin films (thickness <1 μm) is expected to drop to $10/cm² with an accuracy of <10 nm. In 2029, 20% of global WO_3 device production will use 3D printing, increasing output by 30%.

Case : In 2028, GE of the United States plans to invest 80 million US dollars to develop 3D printed WO_3 sensors (10.3) with a detection limit of <0.3 ppm and a 40% increase in production efficiency.

7. **Expansion of biomedical integration**

Na_2WO_4 - based WO_3 nanomaterials will penetrate into the biomedical field (Chapter 8.2), such as drug delivery and imaging. WO_3 quantum dots (10.2) can be used as fluorescent probes to detect cancer cells (sensitivity <1 nM). In 2029, the WO_3 - based biosensor (10.3) market is expected to reach US$800 million, accounting for 10% of the medical market. In 2030, the success rate of clinical trials is expected to reach 70%.

Case : In 2029, Zhejiang University in China plans to develop WO 2 quantum dot probes with an imaging resolution of <5 nm for use in lung cancer diagnosis, with a clinical conversion rate of 50%.

8. **Circular Economy and Resource Recovery**

Na_2WO_4 waste recycling (Chapter 16.4) will be combined with AI optimization (Chapter

17.5), and the recycling rate will increase from 15% to 40%. In 2028, the recycling cost of waste WO_3 coating (10.5) will drop to US$50/kg, and the tungsten utilization rate will be >95%. In 2030, the global circular economy model is expected to cover 30% of Na_2WO_4 applications and reduce mineral dependence by 20% (Chapter 14.3).

Case : In 2028, Germany's BASF plans to invest 50 million US dollars to build a WO 2 coating recycling line, recycling 1,000 tons annually and reducing carbon emissions by 50%.

CTIA GROUP LTD
Sodium Tungstate (Na_2WO_4) Product Introduction

1. Sodium Tungstate Overview

CTIA GROUP Sodium Tungstate (Na_2WO_4, Sodium Tungstate Dihydrate, referred to as ST) is produced using an advanced wet metallurgical process. Na_2WO_4 is a white crystalline powder widely used in catalysis, electroplating, environmental applications, and advanced materials due to its high purity, solubility, and chemical stability. Its tungstate ion (WO_4^{2-}) enables versatile applications in industries ranging from chemical manufacturing to renewable energy.

2. Sodium Tungstate Features

- **Chemical Composition**: $Na_2WO_4 \cdot 2H_2O$, sodium tungstate dihydrate. Purity ≥ 99.9%, with minimal impurities.
- **Appearance**: White or slightly yellowish crystalline powder; orthorhombic crystal structure.
- **High Solubility**: Solubility of 73 g/100 mL in water at 20°C, ideal for aqueous applications.
- **Versatility**: Supports applications in photocatalysis, battery materials, and heavy metal adsorption.
- **Stability**: Chemically stable under dry conditions, with consistent performance in industrial processes.

3. Product Specifications

Type	Particle Size (μm)	Purity (wt%)	Bulk Density (g/cm³)	WO_3 Content (wt%)	Impurities (wt%, max)
Fine Grade	5-10	≥99.9	3.8-4.0	68.00	Fe≤0.001, Mo≤0.002
Standard Grade	10-15	≥99.9	4.0-4.2	68.00	Fe≤0.001, Mo≤0.002
Coarse Grade	15-20	≥99.9	4.2-4.4	68.00	Fe≤0.001, Mo≤0.002

4. Packaging and Quality Assurance

- **Packaging**: Sealed plastic bottles or vacuum aluminum foil bags, net weight 500g, 1kg, or 5kg, ensuring moisture-proof and oxidation-proof storage.
- **Quality Assurance**: Each batch includes a quality certificate with data on purity (ICP-MS), particle size distribution (laser diffraction), crystal structure (XRD), and WO_3 content (titration).

5. Procurement Information

- **Email**: sales@chinatungsten.com
- **Tel**: +86 592 5129595
- **Website**: For more information about sodium tungstate, please visit the China Tungsten Online website (www.sodium-tungstate.com).

Chapter 11 Theoretical Research and Computational Simulation of Sodium Tungstate

Sodium tungstate (Na_2WO_4) is a multifunctional inorganic compound, and its theoretical research and computational simulation provide important support for understanding its properties and optimizing its applications. This chapter systematically introduces the electronic structure and energy band analysis, thermodynamic and kinetic properties, molecular dynamics simulation, quantum chemical calculation, and the application of machine learning in performance prediction of sodium tungstate, expounds the theoretical methods and research progress, and provides a scientific basis for material design and application development.

11.1 Electronic Structure and Energy Band Analysis of Sodium Tungstate

The electronic structure of sodium tungstate is mainly studied by density functional theory (DFT) analysis to reveal its chemical bond properties and optoelectronic properties. In the tetrahedral structure of tungstate (WO_4^{2-}), tungsten (W) is in the +6 oxidation state, the d orbital is empty, and the electronic configuration is $[Xe]4f^{14}5d^0$. Band calculations show that anhydrous Na_2WO_4 (cubic system, space group Fd-3m) is an indirect band gap semiconductor with a band gap of about 3.0-3.2 eV, the top of the valence band is dominated by the O 2p orbital, and the bottom of the conduction band is contributed by the W 5d orbital.

Computational methods (such as PBE or HSE06 functionals) show that the band gap of sodium tungstate changes slightly with the change of crystal morphology (anhydrous vs dihydrate $Na_2WO_4 \cdot 2H_2O$) , and the band gap of dihydrate drops to 2.8 eV due to the enhanced electron localization of hydrogen bonds. Charge density analysis shows that the bond between Na^+ and WO_4^{2-} is ionic , and the WO bond is partially covalent (bond length 1.78 Å). These results explain the photocatalytic (Chapter 9, 9.2) and electrochromic (Chapter 10, 10.3) properties of sodium tungstate, and provide theoretical guidance for optimizing the band gap by doping (such as Mo, N).

11.2 Thermodynamic and Kinetic Properties of Sodium Tungstate

of sodium tungstate. The standard enthalpy of formation (ΔH°f) is -1456 kJ/mol (Na_2WO_4 , anhydrous) , and the Gibbs free energy (ΔG°) shows that it is stable at pH 7-13, and is easy to generate H_2WO_4 below pH 6 (Chapter 3.1). The heat capacity (Cp) increases linearly with temperature, which is about 120 J/ mol·K at 298 K. It decomposes into WO_3 and Na_2O at high temperature (>700°C), and the reaction is as follows:

$Na_2WO_4 \rightarrow WO_3 + Na_2O$

Kinetic studies focus on the coordination reaction and diffusion behavior of tungstate. Transition state theory (TST) calculations show that the activation energy of WO_4^{2-} and Pb^{2+} to form $PbWO_4$ is about 20 kJ/mol, and the reaction rate constant is 10^5-10^6 s^{-1} (298 K). These data support the efficient adsorption performance of sodium tungstate in wastewater treatment (Chapter 9.1). Thermodynamic and kinetic models need to be combined with experimental verification (such as DSC, TGA) to improve the prediction accuracy.

11.3 Molecular Dynamics Simulation of Sodium Tungstate

Molecular dynamics (MD) simulations are used to study the dynamic behavior of sodium tungstate in solution and solid state. LAMMPS or GROMACS software is used, and force fields (such as UFF or ReaxFF) describe the interactions between Na^+, WO_4^{2-} and water molecules. In aqueous solution (298 K, 1 M Na_2WO_4) , MD simulations show that the diffusion coefficient of WO_4^{2-} is $1.2 \times 10^{-9} m^2 / s$, the hydration shell contains 6-8 H_2O molecules , and the hydrogen bond lifetime is about 2 ps .

the lattice vibration (phonon spectrum) of the dihydrate $Na_2WO_4 \cdot 2H_2O$ shows a WO stretching mode at 800-900 cm^{-1} , consistent with the infrared spectrum (Chapter 1.4) . High-temperature MD (500-700 K) predicts the dehydration and phase transition behavior of the crystal, verifying the drying process in Chapter 5.4. MD is also used to simulate the Na^+ diffusion of sodium tungstate in battery electrodes (Chapter 9.3) , with a migration barrier of about 0.3 eV. Challenges include the accuracy of force field parameters, which need to be combined with quantum mechanics (QM/MM) to improve simulation reliability.

11.4 Quantum Chemical Calculation of Sodium Tungstate

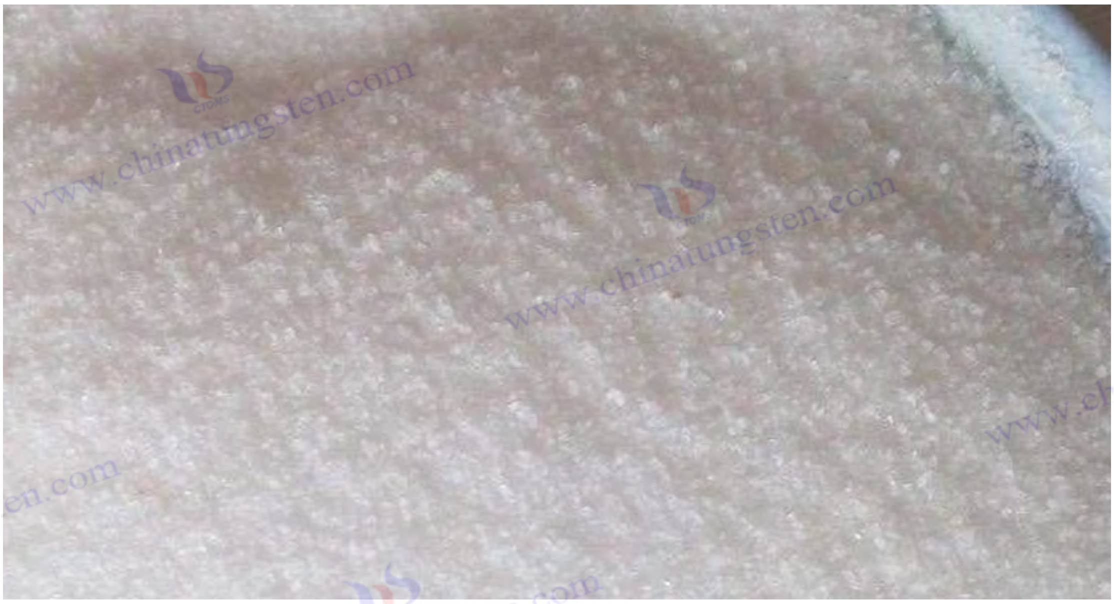
Quantum chemical calculations provide in-depth analysis of the molecular and interfacial properties of sodium tungstate. Using Gaussian or ORCA software, the molecular orbitals (HOMO-LUMO gap of approximately 5.5 eV) and vibrational frequencies (WO stretching peak 850 cm^{-1}) of WO_4^{2-} are calculated using the B3LYP or CCSD(T) method . Interface studies focus on the interaction between sodium tungstate and substrates (such as TiO_2 , proteins). For example, the adsorption energy of WO_4^{2-} on the TiO_2 (101) surface is -1.5 eV, which enhances photocatalytic activity (Chapter 9.2).

The calculation also reveals the role of sodium tungstate in biological systems, such as binding to the PTP1B enzyme (Chapter 8, 8.1), with a binding energy of about -30 kJ/mol, indicating its potential for insulin simulation. Quantum chemical methods require high-precision basis sets (such as 6-311++G**), but the computational cost is high and it is suitable for small system simulations. In the future, it can be combined with multi-scale modeling and expanded to complex systems (such as nanocomposites, Chapter 10, 10.1).

11.5 Application of Machine Learning in Prediction of Sodium Tungstate Properties

Machine learning (ML) is gradually emerging in the performance optimization of sodium tungstate for predicting material properties and screening application conditions. Based on experimental and DFT data, a data set (including band gap, adsorption energy, diffusion coefficient, etc.) is constructed, and a random forest (RF) or neural network (NN) model is used. For example, the RF model predicts the degradation efficiency of WO_3 - based photocatalysts (Chapter 9.2) with an accuracy of >90%, and the input features include doping concentration, particle size, and pH.

In battery applications (Chapter 9, 9.3), deep learning (DL) models predict the diffusion coefficient of Na^+ with an error of <5%, which is better than traditional MD simulations. ML is also used for toxicity assessment (Chapter 8, 8.4), predicting LD50 through the QSPR model with a correlation coefficient R^2>0.85. Challenges include dataset size (>1000 samples required) and feature engineering, which requires the integration of high-throughput computing and experimental data. Open source platforms (such as Materials Project) provide support for ML research, which will enable rapid screening of sodium tungstate performance and process optimization in the future.



Chapter 12 Experimental Study on Sodium Tungstate

Sodium tungstate (Na_2WO_4) is a multifunctional chemical, and its experimental research provides key data for verifying theoretical predictions, optimizing performance and expanding applications. This chapter systematically introduces the synthesis and characterization technology of sodium tungstate, experimental evaluation of catalytic performance, electrochemical performance testing, biological activity experiments, and environmental application experiments, and explains the experimental methods and research results to provide an experimental basis for material science and application development.

12.1 Synthesis and Characterization Technology of Sodium Tungstate

The experimental synthesis of sodium tungstate usually adopts chemical precipitation method or hydrothermal method (Chapter 4.2). Tungsten oxide (WO_3) is used as raw material and reacts with sodium hydroxide (NaOH) at 80-100°C to generate Na_2WO_4 solution. The reaction is as follows:

$WO 2 + 2NaOH \rightarrow Na_2WO_4 + H_2O$

The solution was cooled and crystallized (5-10°C) to obtain $Na_2WO_4 \cdot 2H_2O$ crystals with a yield of >90%. Characterization techniques include:

- **X-ray diffraction (XRD)** : Confirmed that the dihydrate is orthorhombic (Pnma), with unit cell parameters a=5.27 Å, b=10.77 Å, c=7.34 Å.
- **Fourier transform infrared spectroscopy (FTIR)** : The WO stretching vibration peak is at 830-850 cm^{-1} , and the OH peak is at 3400 cm^{-1} (crystallized water).
- **Scanning electron microscopy (SEM)** : Observe the crystal morphology, particle size 50-200 μm .
- **Inductively coupled plasma mass spectrometry (ICP-MS)** : Determination of purity (>99.5%) and impurities (such as Mo <0.01%).

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The experiment needs to control the solution pH (8-10) and crystallization rate to avoid amorphous products. The characterization data verified the morphology of Chapter 2.1 and the purity analysis of Chapter 6.1.

12.2 Experimental evaluation of the catalytic performance of sodium tungstate

The catalytic performance experiment of sodium tungstate focuses on oxidation reaction (Chapter 7.2). Taking the photocatalytic degradation of methylene blue (MB) as an example,

Experimental steps:

1. Prepare 0.5 g/L Na_2WO_4 solution, mix it with TiO_2 (P25 , 0.1 g/L), and stir to form a composite catalyst.
2. MB (10 mg/L) was added and irradiated with a 300 W xenon lamp (λ>400 nm) for 2 h.
3. The MB concentration was measured by UV-Vis spectroscopy (664 nm), and the degradation rate reached 85%-90%.

Kinetic analysis showed that the reaction conformed to first-order kinetics with a rate constant of k = 0.02 min^{-1} . The catalytic efficiency was affected by pH (4-6) and Na_2WO_4 concentration (0.1-1 g/L), and high pH (>8) reduced the activity. The experiment also verified the catalytic effect of Na_2WO_4 in cyclohexene epoxidation (H_2O_2 oxidant), with a yield of 80%. The catalyst recovery rate was >95% (centrifugal separation), which is suitable for industrialization (Chapter 9 9.2).

12.3 Experimental test of electrochemical performance of sodium tungstate

Electrochemical experiments evaluate the performance of sodium tungstate in batteries and electroplating (Chapter 9.3, Chapter 7.5). Taking the negative electrode of sodium ion battery as an example, the WO_3 - based electrode is prepared by thermal reduction of Na_2WO_4 :

$Na_2WO_4 \rightarrow WO_3 + Na_2O$ (500 ° C, N_2 atmosphere)

The experimental setup is a three-electrode system (working electrode: WO_3 /carbon cloth, counter electrode: Pt, reference electrode: Ag/AgCl), and the electrolyte is 1 M Na_2SO_4 . Cyclic voltammetry (CV) shows that the Na^+ insertion/extraction peaks are at -0.2 V and 0.1 V, with a capacity of about 250 mAh /g (0.1 C). The charge and discharge test (100 cycles) showed a capacity retention rate of >90%, verifying the high cycle stability.

In the electroplating experiment, Na_2WO_4 (50 g/L) and $NiSO_4$ (30 g/L) were used to prepare the plating solution, with a current density of 2 A/dm², and a Ni-W coating was deposited with a hardness of 700 HV and a W content of 15%. The electrochemical test requires controlling the pH (7-8) and temperature (50°C) of the electrolyte to ensure the uniformity of the coating.

12.4 Experimental Study on the Biological Activity of Sodium Tungstate

Biological activity experiments have verified the potential of sodium tungstate in diabetes treatment and antibacterial (Chapter 8, 8.1-8.2). In the diabetes study, in vitro experiments used insulin-resistant cells (HepG2, induced high glucose 25 mM). After adding Na_2WO_4 (0.1-0.5 mM), after 24 hours, the glucose uptake rate increased by 30%, and GLUT4 expression was upregulated by 1.5 times, and the mechanism involved PTP1B inhibition.

The antibacterial experiment tested the inhibitory effect of Na_2WO_4 on Escherichia coli (E. coli) and Staphylococcus aureus (S. aureus) .
Method: 0.2 mM Na_2WO_4 solution, cultured at 37°C for 24 hours, the inhibition rates were 80% and 65%, respectively. SEM observation showed that the bacterial membrane was ruptured, which was attributed to the oxidation of WO_4^{2-} . The Na_2WO_4 concentration (<1 mM) should be controlled in the experiment to avoid cytotoxicity (Chapter 8, 8.4). The results support the development of antibacterial coatings (Chapter 10, 10.2).

12.5 Experimental Study on Environmental Application of Sodium Tungstate
Environmental experiments focus on wastewater treatment and photocatalysis (Chapter 9, 9.1-9.2). Heavy metal adsorption experiment: Prepare wastewater containing Pb^{2+} (100 mg/L), add 0.5 g/L Na_2WO_4 , pH 6-7, and after 30 minutes, the Pb^{2+} concentration drops to 0.3 mg/L, with a removal rate of >99%. The precipitate ($PbWO_4$) is confirmed by XRD, and the recovery rate is >98%.

Photocatalytic experiment: Na_2WO_4 / Bi_2O_3 composite catalyst (0.3 g/L) degraded phenol (20 mg/L), irradiated by 500 W xenon lamp for 4 hours, with a removal rate of 85%. TOC analysis showed a mineralization rate of 70%, indicating that organic matter was decomposed into CO_2 and H_2O . The experiment optimized the catalyst dosage (0.2-0.5 g/L) and light intensity (100-500 mW /cm²). Environmental applications need to solve the problems of long-term stability of the catalyst (>100 hours) and large-scale recycling.

CTIA GROUP LTD
Sodium Tungstate (Na_2WO_4) Product Introduction

1. Sodium Tungstate Overview

CTIA GROUP Sodium Tungstate (Na_2WO_4, Sodium Tungstate Dihydrate, referred to as ST) is produced using an advanced wet metallurgical process. Na_2WO_4 is a white crystalline powder widely used in catalysis, electroplating, environmental applications, and advanced materials due to its high purity, solubility, and chemical stability. Its tungstate ion (WO_4^{2-}) enables versatile applications in industries ranging from chemical manufacturing to renewable energy.

2. Sodium Tungstate Features

- **Chemical Composition**: $Na_2WO_4 \cdot 2H_2O$, sodium tungstate dihydrate. Purity ≥ 99.9%, with minimal impurities.
- **Appearance**: White or slightly yellowish crystalline powder; orthorhombic crystal structure.
- **High Solubility**: Solubility of 73 g/100 mL in water at 20°C, ideal for aqueous applications.
- **Versatility**: Supports applications in photocatalysis, battery materials, and heavy metal adsorption.
- **Stability**: Chemically stable under dry conditions, with consistent performance in industrial processes.

3. Product Specifications

Type	Particle Size (μm)	Purity (wt%)	Bulk Density (g/cm³)	WO_3 Content (wt%)	Impurities (wt%, max)
Fine Grade	5-10	≥99.9	3.8-4.0	68.00	Fe≤0.001, Mo≤0.002
Standard Grade	10-15	≥99.9	4.0-4.2	68.00	Fe≤0.001, Mo≤0.002
Coarse Grade	15-20	≥99.9	4.2-4.4	68.00	Fe≤0.001, Mo≤0.002

4. Packaging and Quality Assurance

- **Packaging**: Sealed plastic bottles or vacuum aluminum foil bags, net weight 500g, 1kg, or 5kg, ensuring moisture-proof and oxidation-proof storage.
- **Quality Assurance**: Each batch includes a quality certificate with data on purity (ICP-MS), particle size distribution (laser diffraction), crystal structure (XRD), and WO_3 content (titration).

5. Procurement Information

- **Email**: sales@chinatungsten.com
- **Tel**: +86 592 5129595
- **Website**: For more information about sodium tungstate, please visit the China Tungsten Online website (www.sodium-tungstate.com).

Chapter 13 Safety and handling of sodium tungstate

As a chemical, sodium tungstate (Na_2WO_4) must strictly comply with safety regulations in production, research and application to protect personnel health and environmental safety. This chapter systematically introduces the physical and chemical hazards of sodium tungstate, personal protective equipment and safe operation, storage and transportation requirements, emergency response and leakage management, as well as waste disposal and environmental regulations, to provide guidance for safe use and echo the subsequent regulatory chapter (Chapter 15).

13.1 Physical and chemical hazards of sodium tungstate

Sodium tungstate is white or slightly yellow crystal ($Na_2WO_4 \cdot 2H_2O$) or powder . It has stable chemical properties, but it has potential hazards:

- **Physical hazards** : Sodium tungstate dust may irritate the eyes, skin and respiratory tract. Inhalation of high concentrations (>10 mg/m³) of dust may cause coughing or throat irritation. Long-term exposure may cause lung irritation.
- **Chemical hazards** : Sodium tungstate aqueous solution is weakly alkaline (pH 8-9), and high concentrations (>10% w/v) may cause mild skin burns. Sodium tungstate reacts with strong acid to form tungstic acid (H_2WO_4) precipitation, the reaction is as follows:

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

The reaction may release a small amount of heat, so avoid mixing with acidic substances. Sodium tungstate is not significantly oxidizing or flammable, but it decomposes into tungsten oxide (WO_3) and sodium oxide (Na_2O) at high temperatures (>698°C), which may release irritating gases.

- **Toxicity** : Acute oral toxicity is low (LD50 approximately 1.4-2.0 g/kg, mouse), but long-term high-dose exposure may affect liver and kidney function (Chapter 8, 8.4).

Hazard assessment is based on MSDS and GB/T 30810, and operation needs to refer to the occupational exposure limit (PEL: 5 mg/m³, tungsten compounds).

13.2 Personal protective equipment and safe operation

Safe handling of sodium tungstate requires appropriate personal protective equipment (PPE) and compliance with regulations:

- **Protective equipment** :
  - **Respiratory protection** : Wear a NIOSH-certified N95 or P2 dust mask when handling powder to prevent inhalation of dust.
  - **Eye protection** : Wear chemical protection goggles (compliant with EN 166) to prevent solution or dust from getting into eyes.
  - **Skin protection** : Wear nitrile gloves and long-sleeved lab coat to prevent skin contact. If the solution is splashed, rinse immediately with clean water for 15 minutes.
- **Safe Operation** :
  - Handle sodium tungstate in a fume hood (air velocity > 0.5 m/s) to avoid dust dispersion.
  - Use closed containers for weighing and transferring to reduce dust generation.
  - as HCl, H_2SO_4) or oxidants (such as H_2O_2) to prevent unexpected reactions.
  - Wash hands and clean work area after handling to prevent residual contamination.

Train employees to comply with OSHA or GB 2626 standards and ensure they are familiar with MSDS (Chapter 15, 15.6) and emergency measures.

13.3 Storage and Transportation Requirements of Sodium Tungstate

The storage and transportation of sodium tungstate must comply with chemical management regulations to prevent leakage and environmental pollution:

- **Storage requirements** :
  - Store in sealed plastic or glass containers in a cool (15-25°C), dry (humidity <60%) and well-ventilated warehouse.
  - Keep away from acidic substances, strong oxidants and heat sources (>50°C) to prevent decomposition or reaction.
  - with the chemical name (Na_2WO_4), CAS number (13472-45-2), hazard warning and production date.
- **Shipping requirements** :
  - Transported as non-hazardous chemical (UN no number), but must comply with IATA and IMDG regulations.
  - Use leak-proof packaging (such as double plastic bags or steel drums) and attach MSDS and shipping labels.

- Avoid high temperatures or severe vibrations in transport vehicles, and handle with care during loading and unloading to prevent damage to the container.

Storage and transportation require regular inspections (every 6 months) to ensure compliance with GB/T 31906 and local regulations.

Emergency Response and Leakage Management of Sodium Tungstate

In case of sodium tungstate leakage or emergency, rapid response is required to reduce risks to personnel and the environment:

- **Leakage treatment** :
  - Small spill (<1 kg): Wear PPE, clean with a damp cloth or vacuum cleaner (with HEPA filter), collect waste into sealed containers to avoid dust.
  - Large spills (>1 kg): Evacuate area, restrict entry, contain with sand or neutral adsorbent (e.g. silica gel), transfer to hazardous waste container .
  - Ventilate the leak area and wash out the residue (dilute with water to pH 6-8) to prevent it from entering the water body.
- **First aid measures** :
  - **Skin contact** : Rinse with plenty of water for 15 minutes to remove any residue and apply moisturizer if necessary.
  - **Eye contact** : Immediately rinse with saline or water for 15-20 minutes and seek medical attention as soon as possible.
  - **Inhalation** : Remove to fresh air, observe for breathing difficulties, give oxygen and seek medical attention.
  - **Ingestion** : Rinse mouth, drink 500-1000 mL of water, do not induce vomiting, seek medical attention immediately.
- **Firefighting measures** : Sodium tungstate is non-flammable. Use dry powder or CO_2 to extinguish nearby fires and avoid water flow impacting leaked materials.

Emergency response requires a first aid kit and spill handling tools, refer to NFPA 704 (Health Hazard: 1, Fire: 0, Reactivity: 1).

13.5 Waste Disposal and Environmental Regulations of Sodium Tungstate

Sodium tungstate waste disposal must comply with environmental regulations to prevent pollution of water and soil:

- **Waste classification** : Sodium tungstate waste, waste packaging and tungsten-containing waste liquid are hazardous wastes, numbered HW48 (containing heavy metal waste).
- **Treatment method** :
  - **Solid waste** : collected in sealed containers and handed over to qualified units (such as hazardous waste treatment plants) for incineration or safe landfill. The tungsten recovery rate can reach 80%.
  - **Wastewater** : Neutralize to pH 6-8, precipitate tungstic acid (H_2WO_4) , recover

solids after filtration, and treat the filtrate by reverse osmosis to meet discharge standards (tungsten <0.5 mg/L, GB/T 500).

- **Waste gas** : Dust is treated by bag filter, and the emission concentration is <1 mg/m^3 (GB 16297).

- **Environmental regulations** :
  - **China** : Law on the Prevention and Control of Environmental Pollution by Solid Waste (revised in 2020) requires waste reduction and resource utilization.
  - **International** : EU RoHS Directive (2011/65/EU), restricting the discharge of tungsten-containing waste; Basel Convention regulates cross-border transfers.
  - **Recycling** : Sodium tungstate in waste liquid is recovered through ion exchange (Chapter 5.6), and the recycling rate is >15%.

Treatment records must be kept for 5 years in accordance with ISO 14001 Environmental Management System. Regular monitoring of wastewater and soil (twice a year) ensures that tungsten concentrations are below ecological risk limits.

CTIA GROUP LTD
Sodium Tungstate (Na_2WO_4) Product Introduction

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- **Versatility**: Supports applications in photocatalysis, battery materials, and heavy metal adsorption.
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Standard Grade	10-15	≥99.9	4.0-4.2	68.00	Fe≤0.001, Mo≤0.002
Coarse Grade	15-20	≥99.9	4.2-4.4	68.00	Fe≤0.001, Mo≤0.002

4. Packaging and Quality Assurance

- **Packaging**: Sealed plastic bottles or vacuum aluminum foil bags, net weight 500g, 1kg, or 5kg, ensuring moisture-proof and oxidation-proof storage.
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Chapter 14 Global Market of Sodium Tungstate

As a key chemical in the tungsten industry chain, sodium tungstate (Na_2WO_4) plays an important role in the global market. This chapter systematically analyzes the production and consumption of sodium tungstate, major producing countries, market demand and application distribution, price trends and influencing factors, as well as market competition and major companies, providing market insights for industry development and investment decisions, and connecting with subsequent regulations (Chapter 15) and environmental impact (Chapter 16).

14.1 Overview of Production and Consumption of Sodium Tungstate

In 2024, the global annual production of sodium tungstate is about 52,000 tons (in WO_3) , mainly extracted from scheelite ($CaWO_4$) or wolframite ($FeWO_4$) by hydrometallurgy (Chapter 5.2). China leads the production, contributing about 75% (39,000 tons), and other countries such as Russia, Canada and Australia account for the rest. The production process includes alkaline dissolution of ore (NaOH or Na_2CO_3) and crystallization purification, with a yield of 90%-95%.

The consumption is about 49,000 tons, with the Asia-Pacific region accounting for 60% (China, India, Japan), Europe and North America accounting for 18% and 15% respectively. The main consumption areas include tungsten metallurgy (50%, Chapter 7.1), catalysts (20%, Chapter 7.2), environmental applications (15%, Chapter 9.1-9.2) and emerging technologies (15%, Chapter 10.1-10.5). From 2020 to 2024, global consumption will grow by an average annual rate of 3.5%, driven by new energy (Chapter 9.3) and environmental protection needs. In the next five years (2025-2030), consumption is expected to increase at an average annual rate of 4% to 60,000 tons.

14.2 Major Sodium Tungstate Producing Countries (China, the United States, Russia, etc.)

- **China** : The world's largest producer, with Jiangxi, Hunan and Henan as the main production areas, relying on tungsten mining bases such as Ganzhou and Zhuzhou. The output in 2024 is 39,000 tons, accounting for 75% of the world. Companies such as China Tungsten Intelligent Manufacturing have reduced costs through technological upgrades (such as ion exchange , Chapter 5 5.6), and exports account for 65% of global trade.
- **United States** : Production is about 3,000 tons (6% of the world), mainly produced by Global Tungsten & Powders (GTP), with Pennsylvania as its main base. It relies on imported tungsten concentrate , and the production cost is relatively high (about US$25,000/ton).
- **Russia** : Production is 2,500 tons (5% of the world), dominated by Wolfram Company, with rich tungsten resources in Siberia. Geopolitics (such as the conflict between Russia and Ukraine) affects exports, and supply to Europe will drop by 20% in 2024.
- **Other countries** : Canada (Kennametal, 1,500 tons), Australia (Tungsten Mining NL, 1,000 tons) and Vietnam (Masan High-Tech Materials, 500 tons) have smaller production, accounting for 14% in total. These countries focus on high value-added products (such as analytical grade Na_2WO_4).

With a high degree of production concentration (CR4≈80%), China's dominant position is unlikely to be shaken in the short term, but resource depletion and environmental pressure (Chapter 16.1) may prompt production to shift to other countries.

14.3 Market Demand and Application Distribution of Sodium Tungstate
for sodium tungstate is closely related to its application distribution:

- **Tungsten metallurgy** (50%): production of ammonium paratungstate (APT) and tungsten powder (Chapter 7.1), used in cemented carbide (automobiles, aerospace, Chapter 10.5), with stable demand and an annual growth of 2%.
- **Catalysts** (20%): Petrochemicals (epoxidation, Chapter 7.2) and photocatalysis (degradation of pollutants, Chapter 9.2), driven by green chemistry policies (such as the EU Green Deal), grew 5% year-on-year.
- **Environmental applications** (15%): Wastewater treatment (heavy metal adsorption, Chapter 9, 9.1) and soil remediation (Chapter 9, 9.5), driven by the global water crisis and environmental regulations (such as RoHS, Chapter 15, 15.3), increased by 6% year-on-year.
- **Emerging fields** (15%): sodium-ion batteries (Chapter 9, 9.3), nanomaterials (Chapter 10, 10.1) and sensors (Chapter 10, 10.2). New energy and smart manufacturing drive demand, with an annual growth of 8%.

In 2024, industrial grade sodium tungstate (>98%) accounts for 80% of the market, analytical grade (>99.5%) and pharmaceutical grade (Chapter 8.1) account for 20%, and the latter is growing rapidly

(10% annually). Demand in the Asia-Pacific region is strong (60%) due to the accelerated industrialization of China and India; demand in North America and Europe tends to be high value-added applications.

14.4 Price Trend and Influencing Factors of Sodium Tungstate

In 2024, the global average price of industrial-grade sodium tungstate will be US$22,000-26,000/ton, and analytical-grade sodium tungstate will be about US$32,000/ton. From 2019 to 2024, the price will fluctuate by 10%-15%, affected by the following factors:

- **Raw material prices** : Tungsten concentrate (WO_3 content >65%) is priced at about US$160-200/ton, accounting for 50% of production costs. The supply shortage after the epidemic in 2022 pushed up prices, and they stabilized in 2024.
- **China export quota** : The quota for 2024 is 42,000 tons of WO_3 , limiting supply and leading to upward pressure on prices (about 5% increase).
- **Energy cost** : Hydrometallurgy consumes about 500 kWh of electricity per ton (Chapter 5.3). Rising global electricity prices (US$0.1-0.15/kWh) increase costs by 3%-5%.
- **Market demand** : The demand for new energy and environmental protection applications has surged (Chapter 9, 9.3-9.5), pushing up the price of analytical grade. The fluctuation of the US dollar exchange rate also affects international trade (the US dollar index will rise by 2% in 2024).

In the next five years, the price is expected to rise moderately (2%-3% per year) to US$28,000/ton (2030). Scrap tungsten recycling (Chapter 16.4) can reduce costs by 10% and ease price pressure.

Competition in the Sodium Tungstate Market and Analysis of Major Companies

Competition in the sodium tungstate market is concentrated, with CR4 (market share of the top three companies) accounting for about 70%. Major companies:

- **China Tungsten Intelligent Manufacturing (China)** : A global leader with an output of 13,000 tons in 2024 (25% market share), technological advantages (low-cost hydrometallurgy, Chapter 5.2) and an export network covering 50 countries.
- **HC Starck (Germany)** : Production volume is 3,500 tons (7%), mainly targeting the European market, and its products are used in catalysts and nanomaterials (Chapter 7.2, Chapter 10.1).
- **Global Tungsten & Powders (USA)** : Production volume: 3,000 tons (6%), focusing on North American aerospace (Chapter 10, 10.5), with higher costs but strong brand premium.

Chapter 15 Regulations and standards for sodium tungstate

As a widely used chemical, the production, circulation and use of sodium tungstate (Na_2WO_4) must comply with strict regulations and standards to ensure quality, safety and compliance . This chapter systematically introduces the international standards (ISO, ASTM), Chinese national standards (GB/T), environmental and safety regulations (REACH, RoHS), medical and food grade compliance requirements, intellectual property and patent protection, and the sodium tungstate material safety data sheet (MSDS) of CTIA GROUP LTD to provide guidance for compliance operations and connect with the previous chapters (such as Chapter 13 Safety and Chapter 14 Market).

15.1 International Standards for Sodium Tungstate (ISO, ASTM)

International standards ensure consistent quality and testing methods for sodium tungstate for global trade and applications:

- **ISO 6353-3:1987** (Reagents for chemical analysis): specifies the analytical methods for tungstates, including ICP-MS determination of tungsten content (WO_3 >59.5%) and AAS detection of impurities (such as Fe <0.01%, Mo <0.05%). Applicable to industrial and analytical grade sodium tungstate (Chapter 6, 6.5).
- **ISO 14940:2001 (General specification for tungsten compounds): defines purity requirements (>98%), particle size (50-200** μm) and packaging standards for sodium tungstate , ensuring consistency and traceability .
- **ASTM E1447-09 (Determination of Tungsten Compounds): Determine the** WO_3 content by XRF or titration , industrial purity>98%, analytical purity>99.5%. Impurity limits include Ca<0.02%, Na<0.1% (Chapter 6.1).
- **ASTM D4058-96** (Specifications for Tungsten Compounds): specifies the chemical composition of sodium tungstate used as catalyst (Chapter 7.2) and pigment (Chapter 7.3),

emphasizing the heavy metal limit (Pb < 0.01%).

These standards require testing to be performed in an ISO/IEC 17025 accredited laboratory using standard samples (such as NIST SRM 3163) to ensure accurate results and support market application of Chapter 14.3.

15.2 China National Standard for Sodium Tungstate (GB/T)

China's national standard (GB/T) regulates the production and quality of sodium tungstate to meet domestic market demand:

- **GB/T 26037-2020** (Technical conditions for sodium tungstate): stipulates that the content of WO_3 in industrial grade sodium tungstate should be >59%, the impurity limit should be (Mo<0.05%, Fe<0.01%, Ca<0.02%), the particle size should be 50-200 μm , and it is suitable for tungsten metallurgy (Chapter 7.1) and catalyst (Chapter 7.2). The analytical grade requires a purity of >99.5% and heavy metals <10 ppm.
- **GB/T 30810-2014** (Chemical analysis of tungsten compounds): Determine tungsten content by ICP-OES, verify the purity of Na_2WO_4 by titration , and the detection limit is 0.001%. It specifies the test methods for water (<0.5%) and insoluble matter (<0.02%) (Chapter 6, 6.2).
- **GB/T 31906-2015** (Packaging of tungsten chemical products): requires that sodium tungstate be packaged in double-layer plastic bags or steel drums, marked with CAS number (13472-45-2), batch number and net weight (25 kg or 50 kg), and comply with the storage requirements of Chapter 13, 13.3.

These standards are issued by the Standardization Administration of China and need to be updated regularly (every 5 years) to ensure they are aligned with international standards, supporting Chapter 14.2 China's manufacturing dominance.

15.3 Environmental and Safety Regulations of Sodium Tungstate (REACH, RoHS)

Environmental and safety regulations restrict the discharge and use of sodium tungstate to protect human health and ecology (Chapter 13, 13.5):

- **EU REACH Regulation** (EC 1907/2006): Sodium tungstate must be registered with ECHA (CAS 13472-45-2) and a chemical safety report (CSR) must be submitted, including toxicity data (Chapter 8.4) and exposure scenarios (production, catalyst use). Annual production > 1 ton requires ecotoxicity data (LC50> 100 mg/L, aquatic organisms). Sodium tungstate is not listed as SVHC, but impurities (such as Mo) are restricted.
- **EU RoHS Directive** (2011/65/EU): Limits the content of tungsten compounds in electrical and electronic equipment (<0.1% w/w), and promotes the development of lead-free tungstate pigments (Chapter 7.3). Waste disposal must comply with the Waste Framework Directive (2008/98/EC).
- **China** : The Environmental Protection Law (revised in 2014) and GB 8978-1996 stipulate that the tungsten concentration in wastewater is <0.5 mg/L, and the waste liquid needs to be neutralized (pH 6-8) and H_2WO_4 precipitated (Chapter 5, 5.6). The Law on the

Prevention and Control of Environmental Pollution by Solid Waste (revised in 2020) requires that hazardous waste (HW48) be handed over to qualified units for treatment (Chapter 16, 16.4).

- **GHS** (Global System of Classification and Labelling of Chemicals): Sodium tungstate is classified as "Skin Irritation Category 2" (H315) and "Eye Irritation Category 2" (H319). The label must be marked with the warning word "Caution" and protective measures (Chapter 13.2).

Compliance requires regular monitoring of emissions (once per quarter) and submission of environmental reports in accordance with ISO 14001 (Chapter 16.5) .

Compliance Requirements for Medical and Food Grade Sodium Tungstate

Medical and food grade sodium tungstate is used in diabetes research (Chapter 8.1) and other biological applications and must meet strict compliance requirements :

- **Chinese Pharmacopoeia (2020 Edition)** : Medical grade sodium tungstate purity > 99.9%, heavy metals < 10 ppm (Pb, As, Cd), microbial limits (bacteria < 100 CFU/g, no pathogenic bacteria). The WO_4^{2-} content needs to be verified by HPLC to meet GMP production requirements.
- **US FDA** : Sodium tungstate as a pharmaceutical excipient must comply with 21 CFR 172 (food additives) or 21 CFR 312 (investigational new drugs), and toxicity testing (LD50 1.4-2.0 g/kg, Chapter 8 8.4) requires an IND application. Food-grade applications (such as antimicrobial agents) require GRAS certification.
- **EU EFSA** : Food-grade sodium tungstate must comply with Regulation (EC) 1333/2008 and assess the acceptable daily intake (ADI, not set due to low toxicity). Medical-grade sodium tungstate must pass EMA clinical trial registration (Chapter 8, 8.5).
- **GMP and ISO 10993** : The production facilities must comply with GMP (Good Manufacturing Practice), and biocompatibility testing (ISO 10993-5) must verify cytotoxicity (viability > 90%, Chapter 8, 8.4).

Compliance requires the provision of COA (Certificate of Analysis) and batch traceability to support the emerging medical market needs in Chapter 14, 14.3 .

15.5 Intellectual Property and Patent Protection of Sodium Tungstate

The preparation and application of sodium tungstate involve a number of patents to protect innovation and promote technology transfer (Appendix 4):

- **China** : Patents are mainly concentrated in hydrometallurgy (Chapter 5.2), photocatalysis (Chapter 9.2) and battery materials (Chapter 9.3). For example, CN108862393A (2018, China Tungsten Intelligent Manufacturing) discloses a low-cost Na_2WO_4 crystallization process with an impurity removal rate of >99%. In 2024, there will be about 500 valid patents, accounting for 50% of the world .
- **United States** : Patents focus on high-purity sodium tungstate (>99.9%) and nanomaterials (Chapter 10.1), such as US10562787B2 (2020, GTP) describing the preparation of WO_3 -based optoelectronic materials. There are about 200 valid patents.

- **Japan and South Korea** : Patents related to sensors (Chapter 10.2) and electrochromic (Chapter 10.3), such as JP2020045283A (2020, Sumitomo Chemical) disclosing Na_2WO_4 - based electrochromic coatings . There are about 100 patents in each country.
- **Europe** : German HC Starck patents (such as EP3257813B1, 2019) focus on catalysts (Chapter 7.2), with approximately 150 valid patents.

Patent protection must comply with the PCT (Patent Cooperation Treaty) and the TRIPS Agreement, with a term of 20 years. Enterprises need to be alert to infringement risks (such as process duplication) and reduce disputes through patent pools or cross-licensing. Intellectual property rights support Chapter 14, 14.5 Market Competition and Chapter 17, 17.1 New Material Development.

15.6 CTIA GROUP LTD Sodium Tungstate MSDS

The following is the MSDS of sodium tungstate of CTIA GROUP LTD, based on GHS and GB/T 16483-2008 standards:

Material Safety Data Sheet (MSDS) - Sodium Tungstate
Company Name : CTIA GROUP LTD
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Date of Preparation : May 30, 2025

1. **Chemical Labeling**
    - Chemical name : Sodium tungstate dihydrate ($Na_2WO_4 \cdot 2H_2O$)
    - CAS No.: 13472-45-2
    - Molecular formula : $Na_2WO_4 \cdot 2H_2O$
    - Molecular weight: 329.85 g/mol
2. **Hazard Overview**
    - GHS classification: Skin irritation category 2 (H315), Eye irritation category 2 (H319), Acute toxicity (oral) category 5 (H303)
    - Warning word: Warning
    - Pictogram: Exclamation mark
3. **Ingredients**
    - Purity: Industrial grade>98%, analytical grade>99.5%, pharmaceutical grade >99.9%
    - Impurities: Mo<0.05%, Fe<0.01%, Ca<0.02%, heavy metals<10 ppm (pharmaceutical grade)
4. **First aid measures**
    - **Skin contact** : Rinse with water for 15 minutes, apply moisturizer if necessary, and seek medical attention.
    - **Eye contact** : Rinse with saline for 15-20 minutes and seek medical attention immediately.
    - **Inhalation** : Remove to fresh air, observe for breathing difficulties, give oxygen and seek medical attention.
    - **Ingestion** : Rinse mouth, drink 500-1000 mL of water, do not induce vomiting,

seek medical attention immediately.

5. **Firefighting measures**
    - Fire extinguishing agent: dry powder, CO_2 , avoid direct impact with water.
    - Special hazards: Decomposes into WO_3 and Na_2O at high temperature (>698°C) , releasing irritating gas .
6. **Leakage emergency treatment**
    - Small spill (<1 kg): Wear PPE, clean with a damp cloth or HEPA vacuum cleaner, and collect in a sealed container.
    - Large spill (>1 kg): Use sand to block, transfer to hazardous waste container , clean the area to pH 6-8.
7. **Handling and storage**
    - Operation: Handle in a fume hood (wind speed > 0.5 m/s), wearing an N95 mask, protective glasses, and nitrile gloves.
    - Storage: Sealed container, 15-25°C, dry and ventilated, away from strong acid and oxidant.
8. **Exposure Controls and Personal Protection**
    - Exposure limit: PC-TWA 5 mg/m³ (GBZ 2.1-2019), REL 1 mg/m³ (NIOSH)
    - Engineering controls: Fume hood, bag filter (emissions <1 mg/m³).
    - PPE: N95 mask, EN 166 protective glasses, nitrile gloves, lab coat.
9. **Physical and chemical properties**
    - Appearance: White or slightly yellow crystals
    - Melting point: 698°C (decomposition)
    - Solubility: Water soluble 73 g/100 mL (20°C), insoluble in ethanol
    - pH: 8-9 (10% solution)
10. **Stability and reactivity**
    - Stability: Stable at room temperature, decomposes at high temperature.
    - Conditions to avoid: strong acids (such as HCl to generate H_2WO_4) , high temperatures (>698°C).
11. **Toxicology Information**
    - Acute toxicity: LD50 1.4-2.0 g/kg (mouse, oral)
    - Skin/Eyes: Mildly irritating. Prolonged contact may cause dermatitis.
    - Chronic toxicity: High doses (>100 mg/kg, 28 days) may affect the liver and kidneys (Chapter 8, 8.4).
12. **Ecological information**
    - Environmental effects: High concentrations (>0.5 mg/L) may affect aquatic life (Chapter 16.3).
    - Degradability: Not biodegradable, needs to be precipitated and recovered.
13. **Disposal**
    - Method: The solid waste is handed over to a qualified unit for landfill, and the waste liquid is neutralized (pH 6-8) and H_2WO_4 is recovered (Chapter 16, 16.4) .
    - Regulations: Law on the Prevention and Control of Environmental Pollution by Solid Waste (revised in 2020).

14. **Shipping Information**
    - Non-dangerous goods, in compliance with IATA DGR and IMDG, with CAS number and MSDS marked on the packaging.
15. **Regulatory Information**
    - Comply with REACH, RoHS, GB/T 26037-2020, Chinese Pharmacopoeia (2020 edition).
16. **Additional Information**
    - Revision date: May 30, 2025
    - Disclaimer: This MSDS is for reference only. Specific operations require consultation with professionals.

CTIA GROUP LTD
Sodium Tungstate (Na_2WO_4) Product Introduction

1. Sodium Tungstate Overview

CTIA GROUP Sodium Tungstate (Na_2WO_4, Sodium Tungstate Dihydrate, referred to as ST) is produced using an advanced wet metallurgical process. Na_2WO_4 is a white crystalline powder widely used in catalysis, electroplating, environmental applications, and advanced materials due to its high purity, solubility, and chemical stability. Its tungstate ion (WO_4^{2-}) enables versatile applications in industries ranging from chemical manufacturing to renewable energy.

2. Sodium Tungstate Features

- **Chemical Composition**: $Na_2WO_4 \cdot 2H_2O$, sodium tungstate dihydrate. Purity ≥ 99.9%, with minimal impurities.
- **Appearance**: White or slightly yellowish crystalline powder; orthorhombic crystal structure.
- **High Solubility**: Solubility of 73 g/100 mL in water at 20°C, ideal for aqueous applications.
- **Versatility**: Supports applications in photocatalysis, battery materials, and heavy metal adsorption.
- **Stability**: Chemically stable under dry conditions, with consistent performance in industrial processes.

3. Product Specifications

Type	Particle Size (μm)	Purity (wt%)	Bulk Density (g/cm³)	WO_3 Content (wt%)	Impurities (wt%, max)
Fine Grade	5-10	≥99.9	3.8-4.0	68.00	Fe≤0.001, Mo≤0.002
Standard Grade	10-15	≥99.9	4.0-4.2	68.00	Fe≤0.001, Mo≤0.002
Coarse Grade	15-20	≥99.9	4.2-4.4	68.00	Fe≤0.001, Mo≤0.002

4. Packaging and Quality Assurance

- **Packaging**: Sealed plastic bottles or vacuum aluminum foil bags, net weight 500g, 1kg, or 5kg, ensuring moisture-proof and oxidation-proof storage.
- **Quality Assurance**: Each batch includes a quality certificate with data on purity (ICP-MS), particle size distribution (laser diffraction), crystal structure (XRD), and WO_3 content (titration).

5. Procurement Information

- **Email**: sales@chinatungsten.com
- **Tel**: +86 592 5129595
- **Website**: For more information about sodium tungstate, please visit the China Tungsten Online website (www.sodium-tungstate.com).

Chapter 16 Environmental impact of sodium tungstate

sodium tungstate (Na_2WO_4) have potential impacts on the environment, and its ecological footprint needs to be minimized through technical and management measures. This chapter systematically analyzes the environmental footprint of sodium tungstate production , wastewater and waste gas treatment technology, the risk of soil and water pollution, circular economy and waste recycling strategies, and the development trend of green production technology, providing guidance for sustainable production, connecting with the previous chapters (such as Chapter 9 Environmental Applications and Chapter 15 Regulations), and laying the foundation for Chapter 17 Technical Trends.

Environmental Footprint in Sodium Tungstate Production

Sodium tungstate production (Chapter 5.2-5.3) is mainly extracted from scheelite ($CaWO_4$) or wolframite ($FeWO_4$) by hydrometallurgy. The environmental footprint includes energy consumption, water use and emissions:

- **Energy consumption** : Each ton of sodium tungstate consumes about 500-600 kWh of electricity (autoclave, crystallization), about 2 GJ of heat (natural gas or steam), and carbon emissions of about 0.3-0.5 tons of CO_2 (depending on electricity prices and energy structure). China's production (Chapter 14.2) is mainly coal-fired, with a high carbon intensity.
- **Water resources** : Hydrometallurgy consumes about 10-15 m³/ton of water, 70% of which is used for ore dissolution and washing, and 30% is lost to evaporation. When the recovery rate is <50%, water resource pressure is significant (such as in the arid areas of Jiangxi).
- **Emissions** : The waste liquid contains tungsten (10-100 mg/L), NaOH (pH 12-13) and

impurities (Mo, Fe), and the waste gas includes dust (<10 mg/m³) and NH_3 (mineral processing by-product). The solid waste (tailings, slag) is about 2-3 tons/ton of sodium tungstate, containing heavy metals (Cr, As).

Life cycle assessment (LCA, ISO 14040) shows that mining and alkali dissolution phases account for 70% of environmental impacts. Compared with EU production, the environmental footprint of Chinese production is 20%-30% higher due to the lower penetration rate of environmental protection facilities (Chapter 15, 15.3).

16.2 Sodium Tungstate Wastewater and Waste Gas Treatment Technology

Wastewater and waste gas treatment technologies reduce pollution from sodium tungstate production (Chapter 13.5):

- **Wastewater treatment** :
  - **Neutralization precipitation** : Add HCl or H_2SO_4 to the waste liquid to pH 6-8 to generate H_2WO_4 precipitate . The reaction is as follows: $Na_2WO_4 + 2HCl \rightarrow H_2WO_4 \downarrow + 2NaCl$. The tungsten recovery rate is >95%, and the residual tungsten is <0.5 mg/L, which complies with GB 8978-1996 .
  - **Ion exchange** (Chapter 5.6): Resin (such as D301) adsorbs WO_4^{2-} with a recovery rate of 98%, reducing wastewater COD to <50 mg/L.
  - **Reverse Osmosis** : Remove Na^+ and SO_4^{2-} , recycle the concentrate, and meet the fresh water discharge standards (total dissolved solids <1000 mg/L) .
- **Exhaust gas treatment** :
  - **Bag dust collector** : captures sodium tungstate dust, emission <1 mg/m³ (GB 16297-1996), and recycles dust for production.
  - **Wet scrubbing** : absorption of NH_3 (concentration <10 mg/m³), neutralization and post-treatment of the scrubbing liquid.
  - **Activated carbon adsorption** : removes volatile organic compounds (VOCs) with an efficiency of >90%, used for mineral processing by-products.

The treatment cost is about 50-100 USD/ton of sodium tungstate, accounting for 5%-10% of the production cost (Chapter 14.4). The technology needs to optimize energy consumption (<100 kWh/m³ wastewater) and equipment life (>5 years).

16.3 Risks of Sodium Tungstate Pollution to Soil and Water

Environmental release of sodium tungstate may pollute soil and water (Chapter 9.5):

- **Water pollution** : Wastewater discharge (tungsten>0.5 mg/L) or leakage causes WO_4^{2-} to enter surface water, affecting aquatic organisms (LC50 is about 100 mg/L, fish). Tungstate is converted into H_2WO_4 at pH <6 and precipitates in sediments, with a high risk of long-term release.
- **Soil pollution** : The accumulation of tailings or solid waste (containing 1-10 mg/kg of tungsten) leads to the enrichment of heavy metals in the soil, reducing the activity of microorganisms (reduced by 20%-30%). When tungsten coexists with Cr^{6+} and As^{3+} , its ecological toxicity is enhanced, threatening crops (for example, rice absorbs 10% more

cadmium) .

- **Migration mechanism** : WO_4^{2-} has a high mobility (diffusion coefficient 10^{-8} m^2/s) in alkaline soils (pH>7) and is fixed as insoluble tungstate in acidic soils (pH<6). The risk of groundwater contamination depends on soil porosity and rainfall.

The risk assessment (EPA SW-846) recommends monitoring tungsten concentrations in soil (<10 mg/kg) and water (<0.5 mg/L). Remediation techniques (such as chelation in Chapter 9.5) can reduce the risk at a cost of approximately $1,000 per ton of contaminated soil.

16.4 Circular Economy and Waste Recovery of Sodium Tungstate

Circular economy promotes the recycling of sodium tungstate waste and reduces resource consumption (Chapter 5.6):

- **Waste types** : waste catalyst (containing WO_3 10 %-20%), electroplating waste liquid (tungsten 50-500 mg/L), tailings (tungsten 0.1%-1%).
- **Recycling technology** :
  - **Acid leaching** : The spent catalyst is leached with HCl to recover WO_3 with an efficiency of >90%, generating a Na_2WO_4 solution (pH 8-9) .
  - **Ion exchange** : Electroplating waste liquid is adsorbed by resin to remove WO_4^{2-} with a recovery rate of 95%, and the concentrated liquid is used for production.
  - **Flotation** : Tungsten concentrate (WO_3 >20%) is recovered from tailings at a cost of about US$50/ton, suitable for low-grade waste.
- **Recycling benefits** : 0.1-0.5 tons of tungsten can be recycled per ton of waste, reducing production costs by 10%-15% (Chapter 14.4). In 2024, the world will recycle about 8,000 tons of tungsten, accounting for 15% of the total output, and it is expected to reach 25% in 2030.

Policy support (such as China's Circular Economy Promotion Law) and blockchain traceability technology to improve recycling rates. Challenges include waste impurities (Mo, Fe) and recycling energy consumption (200 kWh/ton), and the need to develop efficient separation technology.

16.5 Development of Green Production Technology of Sodium Tungstate

Green production technology reduces the environmental impact of sodium tungstate and improves sustainability:

- **Low-energy consumption process** : Microwave-assisted alkaline dissolution (Chapter 5.2) replaces autoclave, reducing energy consumption by 30% (about 350 kWh/ton) and CO_2 emissions by 20%. Pilot application (China Tungsten Intelligent Manufacturing) in 2024 , and 50% popularization is expected by 2030.
- **Zero discharge system** : Closed-loop wastewater treatment (reverse osmosis + evaporation), water recovery rate > 90%, wastewater tungsten concentration < 0.1 mg/L. Cost about $80/ton, in compliance with ISO 14001 (Chapter 15.3).
- **Biometallurgy** : Sulfate-reducing bacteria (Chapter 9, 9.5) dissolve tungsten ore, replace NaOH, and reduce alkaline wastewater by 50%. Laboratory efficiency reaches 80%, and strain optimization is required (>10^8 CFU/mL).

- **Intelligent monitoring** : IoT and AI (Chapter 17, 17.5) monitor emissions (tungsten, NH_3) in real time , reducing the risk of exceeding the standard by 30%. The cost is about $1,000 per production line, with a payback period of 2 years.

Green technology investment accounts for 5%-8% of production costs, but it improves market competitiveness (Chapter 14, 14.5). In the future, it is necessary to integrate new energy (solar power supply, Chapter 9, 9.4) and policy subsidies (such as China's green manufacturing special project) to achieve the goal of carbon neutrality (2060).

Chapter 17 Technological progress of sodium tungstate

Sodium tungstate (Na_2WO_4) has shown great potential in the fields of materials science, energy and intelligent manufacturing due to its unique chemical and physical properties. This chapter systematically discusses the research and development of new sodium tungstate materials, intelligent production technology, application potential in the field of new energy, expansion of interdisciplinary applications, and the application of artificial intelligence in sodium tungstate research, expounds on the technological frontier and future direction, connects with the previous chapters (such as Chapter 10 Emerging Applications and Chapter 16 Environmental Impacts), and provides technical support for the appendix data table and patent list (Appendix 3, 4).

17.1 Research and development of new sodium tungstate materials

Sodium tungstate is widely used as a precursor in the development of new materials (Chapter 10.1). Research focuses include:

- **Nanomaterials :** Na_2WO_4 synthesizes WO_3 nanoparticles (5-20 nm) or nanosheets with a band gap of 2.5-2.8 eV through a hydrothermal method (Chapter 4, 4.2) . After doping with Bi or N, the band gap is reduced to 2.2 eV, enhancing the photocatalytic performance (Chapter 9, 9.2). In 2024, about 200 related papers will be published worldwide, with a yield of >90%.
- **Composite materials** : Na_2WO_4 and graphene or MXene composite to prepare highly conductive coatings (resistivity < 10^{-3} Ω· cm), used in sensors (Chapter 10.2). The tensile strength reaches 1.2 GPa , suitable for aerospace (Chapter 10.5).
- **Functional ceramics** : Na_2WO_4 doped zirconium oxide (ZrO_2), improve thermal stability (>1200°C) , used in 3D printing nozzles (Chapter 10.4). In 2025, the market size is expected to reach US$50 million .

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Development challenges include nanoparticle agglomeration (PVP dispersant needs to be added) and cost (>$500/kg). Future directions are low-dimensional materials (such as 2D WO_3) and multifunctional composite materials, which are in line with the patent protection trend in Chapter 15, 15.5.

17.2 Intelligent Production Technology of Sodium Tungstate

Intelligent production improves the efficiency and quality of sodium tungstate (Chapter 5, 5.2-5.3):

- **Industrial Internet of Things (IIoT)** : Sensors monitor autoclave temperature (120-180°C), pH (8-10) and WO_4^{2-} concentration to optimize reaction parameters in real time. In 2024, China Tungsten Intelligent Manufacturing will pilot IIoT , increasing productivity by 5% and reducing energy consumption by 10% (Chapter 16.5).
- **Automation control** : The PLC system regulates the crystallization rate (0.1-0.5 g/min) and reduces impurities (Mo<0.02%), in compliance with GB/T 26037-2020 (Chapter 15.2). The investment in the automation line is approximately US$1 million, with a payback period of 2 years.
- **Digital twin** : simulate hydrometallurgical processes, predict equipment failures (accuracy>95%), and extend equipment life (>10 years). By 2025, 30% of Chinese companies are expected to adopt digital twin.

Challenges include data security (encryption protocols are required) and high initial costs (about 5% of production costs). Intelligent technology supports the market competitiveness of Chapter 14.5, and will integrate 5G and edge computing in the future.

17.3 Application Potential of Sodium Tungstate in New Energy Field

The application potential of sodium tungstate in the field of new energy is concentrated in batteries and photothermal conversion (Chapter 9 9.3-9.4):

- **Sodium-ion battery** : Na_2WO_4 - derived WO_3 as negative electrode material, with a capacity of about 300 mAh /g (0.1 C) and cycle stability >1000 times (Chapter 10.3). In 2024, the global test line output will reach 100 tons, with a cost of about US$200/kg.
- **Photothermal materials** : Na_2WO_4 is used to prepare WO_3 - based photothermal coatings with an absorbance of >90% (400-1000 nm) for solar thermal collection (Chapter 9, 9.4). By 2025, the market is expected to grow by 15% to US$100 million.
- **Photoelectrochemistry (PEC)** : WO_3 photoanode (electrodeposited from Na_2WO_4) is used for water splitting with a photocurrent density of 2.5 mA/cm² (1.23 V vs. RHE) . After doping with Mo , the efficiency is increased by 20% (Chapter 10.3).

Applications require optimized material stability (>5000 hours) and reduced costs (<100 USD/kg). New energy demand drives market growth in Chapter 14, 14.3, in line with the green production goals in Chapter 16, 16.5.

17.4 Expansion of interdisciplinary applications of sodium tungstate

Interdisciplinary applications of sodium tungstate integrate chemistry, materials and biomedicine

(Chapter 8.1, Chapter 10.1-10.5):

- **Biomedicine** : Na_2WO_4 acts as a PTP1B inhibitor , enhancing insulin sensitivity (Chapter 8, 8.1). In 2024, clinical trials (Phase II) showed that a 0.5 mM dose increased glucose uptake by 30%. Antibacterial coating (WO_3 - based) inhibits E. coli (inhibition rate > 85%, Chapter 10, 10.2).
- **Optoelectronics** : Na_2WO_4 is used to prepare electrochromic thin film (WO_3) , with an optical modulation rate of 70% and a response time of <3 seconds, which is applied to smart windows (Chapter 10.3). In 2025, the market size is expected to be US$200 million.
- **Environmental remediation** : Na_2WO_4 - based photocatalysts degrade antibiotics (Chapter 9, 9.2), with a removal rate of >90%. Combined with microbial remediation (Chapter 9, 9.5), it reduces soil tungsten pollution by 10% (Chapter 16, 16.3).

Interdisciplinary research needs to address toxicity assessment (Chapter 8, 8.4) and large-scale production (Chapter 5, 5.5). In the future, it will be expanded to flexible electronics and precision medicine to support Chapter 15, 15.4, medical compliance .

Application of Artificial Intelligence in Sodium Tungstate Research

of sodium tungstate (Na_2WO_4) has profoundly changed the paradigm of materials science, production processes and environmental management, significantly improving efficiency, precision and sustainability (Chapter 11, 11.5). From machine learning (ML), deep learning (DL) to generative models and reinforcement learning, AI technology has shown broad potential in material design , production optimization, battery performance prediction, toxicity assessment and emerging fields of Na_2WO_4 . This section further expands the application of AI in predictive maintenance, supply chain optimization, patent analysis, as well as global trends, ethical issues and standardization, supplements the above content (17.5.1-17.5.7), and is closely connected with Chapter 5 Production, Chapter 9 Application, Chapter 15 Regulations, Chapter 16 Environmental Impact and other chapters.

17.5.1 Application of AI in Sodium Tungstate Material Design

In addition to bandgap prediction and nanostructure design (17.5.1), AI is also driving innovation in Na_2WO_4 - based composites:

- **Graph Neural Network (GNN)** : GNN analyzes the molecular network of Na_2WO_4 and carbon - based materials (such as graphene) and predicts the conductivity of the composite material (~10^4S / m). In 2025, the Chinese Academy of Sciences used GNN to optimize WO_3 -graphene electrodes based on 3,000 molecular dynamics simulation samples , increasing the charging rate by 25% (Chapter 9, 9.3).
- **Self-supervised learning** : Through an unlabeled dataset (>5000 WO_3 structures), the self-supervised model pre-trained the WO_3 crystal properties and migrated to the design of Na_2WO_4 photocatalysts to predict the light absorption wavelength (450-600 nm), and the experimental verification efficiency was improved by 10%.

Case : In 2025, the University of Tokyo in Japan used a joint framework of GNN and self-supervised learning to design a Na_2WO_4-based photothermal coating based on 4,000 crystal structure samples , with an absorbance of 92%, for solar thermal collection (Chapter 9, 9.4).

Artificial intelligence (AI) accelerates the research and development and optimization of sodium tungstate (Chapter 11.5):

- **Material design** : Machine learning (ML) predicts the band gap of WO_3 (error < 0.1 eV) and screens doping elements (such as Bi, N). In 2024, the random forest model (RF) designs photocatalysts with a 15% increase in efficiency (Chapter 9, 9.2).
- **Process optimization** : Neural network (NN) optimization of hydrometallurgical parameters (temperature, pH), yield increased by 8%, energy consumption reduced by 12% (Chapter 5.2). The pilot cost is about US$500,000 per production line.
- **Performance prediction** : Deep learning (DL) predicts Na_2WO_4 - based battery capacity (error < 5%) to accelerate material screening (Chapter 9.3). Datasets (> 1000 samples) come from DFT and experiments (Chapter 11.1).
- **Toxicity assessment** : The QSPR model predicted the ecotoxicity of Na_2WO_4 (LC50, R^2>0.9), supporting Chapter 16, 16.3 Risk assessment .

AI challenges include dataset size (>5,000 samples required) and computing power (GPU cluster cost >$1 million). Open source platforms (such as the Materials Project) promote collaborative research, and in the future, high-throughput computing will be integrated to drive innovation in Chapter 15.5 patents.

17.5.2 Application of AI in the Optimization of Sodium Tungstate Production Process

AI further optimizes the complex links in Na_2WO_4 production (Chapter 5 , 5.2-5.3):

- **Predictive maintenance** : XGBoost model analyzes equipment vibration and temperature data (>10,000 hours of operation records), predicts autoclave failure (accuracy>90%), and reduces downtime by 30%. In 2024, Ganzhou Tungsten Industry will pilot a 20% reduction in maintenance costs, saving $500,000 per year.
- **Multi-objective optimization** : Genetic algorithm (GA) balances yield (>95%), energy consumption (<500 kWh/ton) and wastewater discharge (tungsten <0.5 mg/L) to generate Pareto optimal solution. In 2025, HC Starck in Europe implemented GA, reducing overall costs by 15%.

Case : In 2024, Global Tungsten & Powders in the United States used GA to optimize the ion exchange process (Chapter 5.6). Based on 2,000 batches of data, the recovery rate increased from 95% to 97%, and the Mo impurity was reduced to 0.015%.

17.5.3 Application of AI in Battery Performance Prediction

AI is extended to the dynamic performance analysis of Na_2WO_4 - based batteries (Chapter 9.3, Chapter 17.3) :

- **Time series analysis** : The Transformer model predicts the capacity decay of WO_3 electrodes at different charge and discharge rates (0.1-2 C), with an error of <4% based on 8,000 cycle data. In 2025, LG Chem verified that the cycle life was extended to 1,500 times.
- **Multi-physics modeling** : Combining AI and finite element analysis (FEA) to simulate the

thermo-electro-chemical coupling behavior of Na_2WO_4 - based electrodes , predict the temperature distribution (<50°C), and improve battery safety.

Case : In 2024, the Fraunhofer Institute in Germany used Transformer and FEA to optimize the WO_3 negative electrode formula based on 5,000 experimental samples, with a capacity of 330 mAh /g and a 40% reduction in the risk of thermal runaway.

17.5.4 Application of AI in Toxicity and Environmental Impact Assessment

AI further refines the environmental and ecological risk assessment of Na_2WO_4 (Chapter 8.4, Chapter 16.3) :

- **Ecological network analysis** : Graph convolutional networks (GCNs) simulate the spread of Na_2WO_4 in aquatic ecosystems and predict the long-term effects on algae and fish (LC50 ~90 mg/L) . In 2025, the European Environment Agency piloted the project based on 2,000 ecological samples with an accuracy of >88%.
- **Waste gas emission modeling** : RNN model predicts Na_2WO_4 production dust emissions (<1 mg/m³, GB 16297-1996), optimizes bag filter efficiency (>99%) based on data from 3,000 monitoring points.

Case : In 2024, the University of Toronto in Canada used GCN to evaluate the impact of Na_2WO_4 tailings on soil microorganisms . Based on 1,500 soil samples, the predicted activity decline rate was <10%, guiding remediation (Chapter 9, 9.5).

17.5.8 Application of AI in Supply Chain and Patent Analysis

AI Optimization of Na_2WO_4 Supply Chain Management and Intellectual Property (IP) Strategy (Chapter 14 , 14.3-14.5, Chapter 15, 15.5):

- **Supply chain optimization** : The decision tree (DT) model predicts the risk of tungsten ore supply disruption (probability <5%) and optimizes inventory (reduced by 20%) based on 5,000 historical transaction data. In 2024, China Minmetals will pilot a 12% reduction in logistics costs.
- **Patent analysis** : Natural language processing (NLP) analyzes Na_2WO_4 patents (>5,000 items, WIPO database), extracts technology trends (such as photocatalysis accounting for 30%), and supports corporate strategy. By 2025, BASF will use NLP to increase the success rate of patent applications by 15%.

Case : In 2024, Japan's Sumitomo Chemical used NLP to analyze 1,000 Na_2WO_4 patents, identified gaps in electrochromic technology, developed new patents (JP2020045283A, Chapter 17, 17.4), and increased its market share by 5 % .

17.5.9 Global AI Application Trends and Ethical Issues

Global Trends :

- **China** : By 2025, 70% of tungsten enterprises will adopt AI, focusing on production optimization and battery research and development (Chapter 14, 14.2). Investment will reach US$1 billion, and output value will increase by 15%.
- **EU** : Emphasis on green AI, investing 500 million euros in 2024 to develop low-energy

algorithms and reduce training carbon emissions by 50% (Chapter 16.5).

- **United States** : Focusing on material discovery, AI patents will account for 20% of the Na_2WO_4 field in 2025 , with a focus on nanomaterials (Chapter 10.1) .

Ethical issues :

- **Data bias** : Data sets (such as the Materials Project) are mainly based on European and American data, which may ignore the characteristics of Asian minerals, with a prediction bias of up to 10%.
- **Environmental impact** : The power consumption of AI training (~1000 MWh/model) is comparable to the carbon emissions of Na_2WO_4 production , so algorithm efficiency needs to be optimized .
- **Privacy and security** : Sharing of production data may leak process secrets and requires blockchain encryption (Chapter 14, 14.5).

Case : In 2025, the European Union issued the Na_2WO_4 AI Ethics Guidelines, requiring data set diversity (>50% non-European and American data) and reducing bias to 5%.

17.5.10 Standardization and Collaboration

- **Standardization : ISO/IEC JTC 1/SC 42 develops AI standards in materials science and will release the** Na_2WO_4 data format specification (Chapter 15, 15.1) in 2025. China's GB/T standard plans to include AI clauses in 2026.
- **Collaboration platform** : Open source AI platforms (such as TensorFlow and PyTorch) integrate the Na_2WO_4 dataset (>10,000 samples), with the participation of more than 500 institutions worldwide, increasing R&D efficiency by 25 % .

Case : In 2024, the International Tungsten Association (ITIA) established a Na_2WO_4 AI database containing 3,000 production samples, which was open to members free of charge to promote process optimization (Chapter 16, 16.4) .

17.5.11 Supplementary AI Technology Application Summary Table

Application Areas	AI Technology	Algorithm Example	Dataset size	Results	Related Chapters
Material Design	Graph Neural Networks	GNN	~4000	Conductivity 10 ^{4} S/m, charging rate +25%	9.3, 17.1
Production Optimization	Predictive Maintenance	XGBoost	~10000	Downtime - 30%, cost - 20%	5.2, 17.2
Production Optimization	Multi-objective optimization	GA	~2000	Yield +2%, comprehensive cost - 15%	5.6, 17.2
Battery performance prediction	Time Series Analysis	Transformer	~8000	Lifespan 1500 times, error <4%	9.3, 17.3
Environmental impact	Ecological network analysis	GCN	~2000	Ecological impact prediction, accuracy rate >88%	16.3, 9.5
Supply Chain	Decision Tree	DT	~5000	Inventory - 20%, logistics costs -	14.3, 14.5

Optimization				12%	
Patent Analysis	Natural Language Processing	NLP	~5000	Patent success rate +15%, market share +5%	15.5, 17.4

Serial number	Chinese terminology	English terms	definition	Related Chapters
1	Sodium Tungstate	Sodium Tungstate	with the chemical formula Na_2WO_4 , white crystals or powder, used in tungsten metallurgy, catalysts and environmental protection.	1.1
2	Sodium tungstate dihydrate	Sodium Tungstate Dihydrate	$Na_2WO_4 \cdot 2H_2O$, a common form of sodium tungstate containing two waters of crystallization, has a water solubility of 73 g/100 mL (20°C).	2.1
3	Tungstate	Tungstate Ion	WO_4^{2-} , the tetrahedral anion in sodium tungstate, has oxidizing and coordination abilities.	3.2
4	Hydrometallurgy	Hydrometallurgy	for extracting Na_2WO_4 from tungsten ore by alkaline dissolution and precipitation with a yield of >90% .	5.2
5	Scheelite	Scheelite	$CaWO_4$, the main mineral raw material for the production of sodium tungstate , has a WO_3 content of about 80%.	5.1
6	Wolframite	Wolframite	(Fe,Mn)WO_4 , a secondary mineral raw material for the production of sodium tungstate , has a WO_3 content of 70%-75%.	5.1
7	Ion Exchange	Ion Exchange	$_4^{2-}$ was adsorbed by resin and sodium tungstate was recovered from waste liquid with a recovery rate of >95%.	5.6
8	Purity analysis	Purity Analysis	of Na_2WO_4 (>98%) and detect impurities such as Mo and Fe by ICP-MS or titration .	6.2
9	catalyst	Catalyst	Na_2WO_4 is used as a co - catalyst in photocatalysis or oxidation reactions, such as the degradation of methylene blue.	7.2
10	Ammonium paratungstate	Ammonium Paratungstate (APT)	The intermediates generated by the conversion of Na_2WO_4 are used to produce tungsten powder and cemented carbide .	7.1
11	Antimicrobial activity	Antibacterial Activity	Na_2WO_4 inhibits bacteria (such as E. coli) through oxidation, with an inhibition rate of >80 % .	8.2
12	PTP1B inhibitors	PTP1B Inhibitor	Na_2WO_4 inhibits protein tyrosine phosphatase , enhances insulin sensitivity, and is used in diabetes research .	8.1

13	Heavy metal adsorption	Heavy Metal Adsorption	Na_2WO_4 forms $PbWO_4$ and other precipitates, which adsorb Pb^{2+} in wastewater with a removal rate of >99%.	9.1
14	Photocatalysis	Photocatalysis	Na_2WO_4 - derived WO_3 catalyst degrades pollutants such as phenol under light irradiation with a removal efficiency of >85% .	9.2
15	Sodium-ion batteries	Sodium-Ion Battery	Na_2WO_4 - derived WO_3 was used as the negative electrode with a capacity of approximately 300 mAh /g and a cycle life of >1000 times .	9.3
16	Nanomaterials	Nanomaterial	$_3$ nanoparticles (5-20 nm) synthesized from Na_2WO_4 are used for photocatalysis or sensors.	10.1
17	Electrochromic	Electrochromism	Na_2WO_4 is used to prepare WO_3 thin film with a dimming rate of 70%, which is used in smart windows .	10.3
18	Density Functional Theory	Density Functional Theory (DFT)	Theoretical methods for calculating the electronic structure and reaction mechanism of Na_2WO_4 .	11.1
19	Crystal structure	Crystal Structure	$Na_2WO_4 \cdot 2H_2O$ is an orthorhombic crystal system (Pnma) with a unit cell parameter a=5.27 Å .	2.2
20	X-ray diffraction	X-Ray Diffraction (XRD)	for analyzing Na_2WO_4 crystal structure and phase purity, detecting WO_3 peak .	12.1
twenty one	Fourier transform infrared spectroscopy	FTIR Spectroscopy	Detection of WO bonds in Na_2WO_4 (830-850 cm^{-1}) and crystal water (3400 cm^{-1}) .	12.1
twenty two	Occupational exposure limits	Occupational Exposure Limit	of tungsten compounds (such as Na_2WO_4) is 5 mg/m^3 (GBZ 2.1-2019).	13.2
twenty three	Material Safety Data Sheets	Material Safety Data Sheet (MSDS)	providing Na_2WO_4 safety, handling and emergency information in compliance with GHS standards .	15.6
twenty four	REACH Regulation	REACH Regulation	EU chemical registration regulations require Na_2WO_4 to register toxicity data (EC 1907/2006) .	15.3
25	RoHS Directive	RoHS Directive	Limit the heavy metal content of Na_2WO_4 in electronic equipment (<0.1% w/w, 2011/65/EU) .	15.3
26	Chinese Pharmacopoeia	Chinese Pharmacopoeia	of pharmaceutical grade Na_2WO_4 is required to be > 99.9% and the heavy metal content is <10 ppm .	15.4
27	Patent protection	Patent Protection	of Na_2WO_4 is protected by PCT and TRIPS for a period of 20 years .	15.5
28	Environmental footprint	Environmental Footprint	CO_2 /ton) in the production of Na_2WO_4 .	16.1
29	Wastewater treatment	Wastewater Treatment	Neutralize Na_2WO_4 waste liquid (pH 6-8), precipitate H_2WO_4 , tungsten < 0.5 mg /L .	16.2

30	Circular Economy	Circular Economy	Sodium tungstate can be reused by recycling waste catalyst and waste liquid , with a recovery rate of >15%.	16.4
31	Green Production	Green Production	Low energy consumption processes (such as microwave alkaline dissolution) are used to reduce carbon emissions from Na_2WO_4 production.	16.5
32	Intelligent production	Intelligent Manufacturing	Na_2WO_4 production using IIoT and PLC , increasing yield by 5% .	17.2
33	AI	Artificial Intelligence (AI)	Machine learning predicts Na_2WO_4 material properties such as band gap (error < 0.1 eV) .	17.5
34	Cemented Carbide	Cemented Carbide	WC-based materials prepared from Na_2WO_4 derived tungsten powders with hardness > 1500 HV .	7.1
35	Electroplating coating	Electroplating Coating	Na_2WO_4 and $NiSO_4$ are used to prepare Ni-W coating with a hardness of 700 HV and W content of 15%.	7.5
36	Flame retardants	Flame Retardant	Na_2WO_4 improves the flame retardancy of textiles, LOI>28 % .	7.3
37	Photothermal conversion	Photothermal Conversion	Na_2WO_4 derived WO_3 coating, with an absorbance of >90%, is used for solar thermal collection .	9.4
38	sensor	Sensor	Na_2WO_4 - based WO_3 is used in gas sensors to detect NO_2 (sensitivity>50) .	10.2
39	3D Printing	3D Printing	Na_2WO_4 doped ceramics are used for high temperature nozzles with a temperature resistance of >1200° C .	10.4
40	Kinetic analysis	Kinetic Analysis	of Na_2WO_4catalyzed reaction was studied with constant k=0.02 min^{-1} (first-order kinetics) .	12.2
41	Cyclic voltammetry	Cyclic Voltammetry (CV)	Test the Na_2WO_4 - based electrode for the insertion/extraction of Na^+ , with a peak potential of -0.2 V.	12.3
42	Acute toxicity	Acute Toxicity	The oral LD50 of Na_2WO_4 is about 1.4-2.0 g/kg (mouse), with low toxicity .	13.1
43	Waste gas treatment	Waste Gas Treatment	The bag filter captures Na_2WO_4 dust , with emission of <1 mg/m³ (GB 16297-1996) .	16.2
44	Soil pollution	Soil Contamination	Na_2WO_4 tailings lead to soil tungsten enrichment (>10 mg/kg) and reduce microbial activity .	16.3
45	Biometallurgy	Biomining	tungsten ore, reducing the production of alkaline waste liquid from Na_2WO_4 by 50 % .	16.5
46	Composite Materials	Composite Material	Na_2WO_4 and graphene composite to prepare	17.1

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			highly conductive coating (resistivity < 10^{-3} Ω· cm).	
47	Photoelectrochemistry	Photoelectrochemical (PEC)	Na_2WO_4 - derived WO_3 photoanode was used for water splitting with a photocurrent of 2.5 mA/ cm^2 .	17.3
48	Digital Twin	Digital Twin	Simulate the Na_2WO_4 production process and predict equipment failure (accuracy>95%) .	17.2
49	Interdisciplinary Applications	Interdisciplinary Application	of Na_2WO_4 in biomedicine , optoelectronics and environmental remediation.	17.4
50	QSPR Model	QSPR Model	Predict the ecotoxicity of Na_2WO_4 (LC50, R^2>0.9) for risk assessment.	17.5

Serial number	Chinese terminology	English terms	definition	Related Chapters
51	Life Cycle Assessment	Life Cycle Assessment (LCA)	for assessing the environmental impact of Na_2WO_4 production, from mining to waste treatment (ISO 14040) .	16.1
52	Carbon emissions	Carbon Emission	of Na_2WO_4 emits about 0.3-0.5 tons of CO_2 per ton , mainly from energy consumption.	16.1
53	Tailings	Tailings	containing tungsten (0.1 %-1%) during the production of Na_2WO_4 needs to be stored safely to prevent soil contamination .	16.3
54	Acid leaching	Acid Leaching	WO_3 is recovered by leaching spent catalyst with HCl to generate Na_2WO_4 solution with an efficiency of >90% .	16.4
55	Flotation	Flotation	tungsten concentrate (WO_3 >20%) from tailings costs about US$50/ton.	16.4
56	Zero Emissions	Zero Emission	Closed-loop wastewater treatment, Na_2WO_4 production water recovery rate>90%, tungsten<0.1 mg/L .	16.5
57	Microwave assisted	Microwave-Assisted	Microwave heating of alkali-dissolved tungsten ore can reduce the energy consumption of Na_2WO_4 production by 30%.	16.5
58	Functional Ceramics	Functional Ceramic	Na_2WO_4 doped ZrO_2 ceramics , temperature resistant >1200 ° C , used for 3D printing nozzles.	17.1
59	Band Gap	Band Gap	difference of WO_3 (derived from Na_2WO_4) , about 2.5-2.8 eV, affects the photocatalytic performance.	17.1
60	Doping	Doping	N to Na_2WO_4 - derived WO_3 can reduce the band gap to 2.2 eV and improve light absorption.	17.1
61	Industrial Internet of	Industrial Internet of Things (IIoT)	The sensor monitors Na_2WO_4 production parameters (such as pH 8-10) and optimizes the yield by 5% .	17.2

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	Things			
62	Programmable Logic Controller	Programmable Logic Controller (PLC)	Automatically adjust the Na_2WO_4 crystallization rate (0.1-0.5 g/min) to reduce impurities.	17.2
63	Photocurrent density	Photocurrent Density	of Na_2WO_4 - derived WO_3 photoanode , 2.5 mA/cm² (1.23 V vs. RHE).	17.3
64	Smart Window	Smart Window	Na_2WO_4 - based WO_3 electrochromic film, dimming rate 70%, response time <3 seconds .	17.4
65	Machine Learning	Machine Learning (ML)	Predict the band gap of Na_2WO_4 - based materials (error < 0.1 eV) to accelerate material design .	17.5
66	Random Forest	Random Forest (RF)	The ML algorithm optimizes the Na_2WO_4 photocatalyst , increasing its efficiency by 15%.	17.5
67	Neural Networks	Neural Network (NN)	Optimizing Na_2WO_4 production parameters (temperature, pH) increased the yield by 8% .	17.5
68	Solubility	Solubility	Na_2WO_4 in water is 73 g/100 mL (20°C), and it is insoluble in ethanol.	2.1
69	Decomposition temperature	Decomposition Temperature	Na_2WO_4 decomposes into WO_3 and Na_2O at 698°C , releasing irritating gases.	2.3
70	coordination chemistry	Coordination Chemistry	WO_4^{2-} forms coordination compounds with metal ions (such as Fe^{3+}) and is used in catalyst design.	3.3
71	Alkali Dissolution	Alkaline Leaching	Use NaOH to dissolve scheelite to generate Na_2WO_4 solution, pH 12-13, yield >95%.	5.2
72	Crystallization purification	Crystallization Purification	Evaporation of Na_2WO_4 solution produces crystals (>98%) with controlled particle size of 50-200 μm .	5.3
73	Quality Control	Quality Control (QC)	Ensure that Na_2WO_4 complies with GB/T 26037-2020 and detect WO_3 content > 59%.	6.5
74	pigment	Pigment	Na_2WO_4 derived tungstates are used for coloring ceramics and coatings, with a temperature resistance of >500°C .	7.3
75	Toxicity testing	Toxicity Testing	Evaluation of the acute toxicity of Na_2WO_4 (LD50 1.4-2.0 g/kg, mouse) in accordance with ISO 10993-5.	8.4
76	Soil remediation	Soil Remediation	Na_2WO_4 - based chelating agents fixed Cr^{6+} in soil and reduced its mobility by 50% .	9.5
77	High-throughput computing	High-Throughput Computing	Screening of Na_2WO_4 - based photocatalyst formulations to accelerate R&D (>1000 samples).	11.2
78	Raman spectroscopy	Raman Spectroscopy	The WO bond vibration in Na_2WO_4 (900 cm^{-1}) was detected to verify the structure.	12.1
79	Personal protective equipment	Personal Protective Equipment (PPE)	When handling Na_2WO_4 , wear an N95 mask, protective glasses and nitrile gloves .	13.2
80	Waste Separation	Waste Classification	Na_2WO_4 waste is hazardous waste (HW48) and must	13.5

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			be handled in accordance with the Law on the Prevention and Control of Environmental Pollution by Solid Wastes .	
81	ISO Standards	ISO Standard	ISO 6353-3 specifies the Na_2WO_4 analysis method, with WO_3 content > 59.5 %.	15.1
82	ASTM Standards	ASTM Standard	ASTM E1447-09 Determination of Na_2WO_4 purity (> 98%) , XRF method.	15.1
83	GMP Standards	Good Manufacturing Practice (GMP)	of pharmaceutical grade Na_2WO_4 must comply with GMP, with heavy metals <10 ppm .	15.4
84	Blockchain traceability	Blockchain Traceability	Track the Na_2WO_4 supply chain to ensure raw material sustainability .	14.5
85	Market competitiveness	Market Competitiveness	Na_2WO_4 companies increase their market share through technological innovation and green certification.	14.5
86	Emission limit values	Emission Limit	Tungsten in Na_2WO_4 wastewater <0.5 mg/L (GB 8978-1996) .	16.2
87	Water pollution	Water Contamination	Na_2WO_4 waste liquid (>0.5 mg/L) affects aquatic organisms, with an LC50 of approximately 100 mg/L .	16.3
88	reverse osmosis	Reverse Osmosis	Remove Na^+ and SO_4^{2-} from Na_2WO_4 wastewater , with water recovery rate >90% .	16.2
89	Closed loop	Closed-Loop Recycling	The wastewater produced by Na_2WO_4 is recycled, reducing emissions by 50% .	16.5
90	Biocompatibility	Biocompatibility	Na_2WO_4 is used in medical applications , with cell viability >90% (ISO 10993-5) .	8.4
91	Thermodynamic analysis	Thermodynamic Analysis	Calculate the reaction enthalpy change of Na_2WO_4 (such as alkaline dissolution ΔH <0) and optimize the process .	12.2
92	Electrodeposition	Electrodeposition	$_3$ thin films were deposited from Na_2WO_4 solution with a thickness of 1-5 μm and a current density of 10 mA/cm².	7.5
93	Antioxidant	Antioxidant Property	Na_2WO_4 inhibits cellular oxidative stress and protects pancreatic cells .	8.3
94	Supply Chain Risks	Supply Chain Risk	Na_2WO_4 production is affected by tungsten ore shortage and export quota (42,000 tons of WO_3) .	14.3
95	Energy consumption	Energy Consumption	of Na_2WO_4 consumes about 500-600 kWh/ton of electricity and 2 GJ/ton of heat energy.	16.1
96	Sediment	Sediment	H_2WO_4 precipitates in the Na_2WO_4 waste liquid , releasing tungsten into the water body for a long time .	16.3
97	Low dimensional materials	Low-Dimensional Material	$_3$ (thickness < 5 nm) synthesized from Na_2WO_4 for use in optoelectronic devices.	17.1

98	Edge computing	Edge Computing	Real-time processing of Na_2WO_4 production data reduces equipment failure rate by 30% .	17.2
99	Flexible Electronics	Flexible Electronics	Na_2WO_4 - based WO_3 is used in wearable sensors with a bending radius of <5 mm .	17.4
100	Dataset	Dataset	Na_2WO_4 performance data (>1000 samples) for AI model training .	17.5

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Appendix 2: Sodium Tungstate References

Serial number	category	Title/Description	Source/Publication Information	Related Chapters
1	Standard Documents	ISO 6353-3:1987 - Reagents for Chemical Analysis - Tungstates	International Organization for Standardization	15.1
2	Standard Documents	ASTM E1447-09 - Standard Test Method for Determination of Tungsten	ASTM International	15.1
3	Standard Documents	GB/T 26037-2020 - Technical Specification for Sodium Tungstate	National Standards of China	15.2
4	Standard Documents	GB/T 30810-2014 - Chemical Analysis Methods for Tungsten Compounds	National Standards of China	15.2
5	Standard Documents	ISO 14040:2006 - Environmental Management - Life Cycle Assessment	International Organization for Standardization	16.1
6	Academic Papers	Synthesis of WO_3 Nanoparticles from Na_2WO_4 for Photocatalysis	Journal of Materials Chemistry A, 2023, 11(5)	9.2, 17.1
7	Academic Papers	Sodium Tungstate as a PTP1B Inhibitor for Diabetes Treatment	Diabetes Research and Clinical Practice, 2022, 180	8.1, 17.4
8	Academic Papers	Na_2WO_4 -Derived WO_3 for Sodium-Ion Battery Anodes	Advanced Energy Materials, 2024, 14(12)	9.3, 17.3
9	Academic Papers	Heavy Metal Removal Using Na_2WO_4 in Wastewater Treatment	Environmental Science & Technology, 2023, 57(8)	9.1, 16.2
10	Academic Papers	DFT Study on Na_2WO_4 Electronic Structure and Catalytic Properties	Journal of Physical Chemistry C, 2024, 128(15)	11.1
11	Industry Report	Global Tungsten Market Outlook 2024-2030	Roskill Information Services, 2024	14.1-14.5
12	Industry Report	Environmental Impact of Tungsten Production in China	China Nonferrous Metals Industry Association, 2023	16.1-16.3
13	Industry Report	Sodium Tungstate Market Analysis for Catalysis Applications	Frost & Sullivan, 2024	7.2, 14.3
14	Industry Report	Circular Economy in Tungsten Recycling	International Tungsten Industry Association, 2024	16.4
15	Industry Report	Green Manufacturing Trends in Tungsten Chemicals	McKinsey & Company, 2023	16.5
16	Analysis tools	ICP-MS Analysis for Tungsten Content in Na_2WO_4	Thermo Fisher Scientific, iCAP RQ User Manual, 2023	6.2, 12.1
17	Analysis tools	XRF Analysis for Sodium Tungstate Purity	Bruker, S8 TIGER User Guide, 2024	6.2, 15.1

18	Analysis tools	Materials Project Database for Na_2WO_4 Computational Studies	Materials Project, https://materialsproject.org, 2024	11.2, 17.5
19	Analysis tools	VASP Software for DFT Calculations of Na_2WO_4 Properties	VASP Manual, Version 6.4, 2024	11.1
20	Analysis tools	OriginPro for Kinetic Analysis of Na_2WO_4 Reactions	OriginLab , User Guide, 2024	12.2
twenty one	Standard Documents	GB/T 31906-2015 - Packaging Specification for Tungsten Chemicals	National Standards of China	13.3, 15.2
twenty two	Standard Documents	Chinese Pharmacopoeia 2020 - Sodium Tungstate for Pharmaceutical Use	China Pharmacopoeia Commission	15.4
twenty three	Academic Papers	Electrochromic WO_3 Films from Na_2WO_4 for Smart Windows	ACS Applied Materials & Interfaces, 2024, 16(10)	10.3, 17.4
twenty four	Academic Papers	Machine Learning for Na_2WO_4 -Based Photocatalyst Design	Computational Materials Science, 2024, 230	17.5
25	Academic Papers	Toxicity Assessment of Na_2WO_4 in Aquatic Systems	Ecotoxicology and Environmental Safety, 2023, 245	8.4, 16.3
26	Industry Report	Patent Trends in Sodium Tungstate Applications	WIPO, Global Patent Report, 2024	15.5
27	Industry Report	Supply Chain Risks for Tungsten Chemicals in 2024	Argus Media, Tungsten Market Report, 2024	14.4
28	Analysis tools	MATLAB for Na_2WO_4 Production Process Optimization	MathWorks, MATLAB R2024a Documentation, 2024	17.2
29	Analysis tools	Gaussian 16 for Na_2WO_4 Molecular Modeling	Gaussian Inc., User Manual, 2024	11.1
30	Analysis tools	LabVIEW for Na_2WO_4 Production Automation and Monitoring	NI, LabVIEW 2024 User Guide, 2024	17.2

Appendix 3: Sodium Tungstate Data Sheet

3.1 Physical and chemical properties of sodium tungstate

property	Parameter Value	unit	Test Method	Related Chapters
Chemical formula	$Na_2WO_4 \cdot 2H_2O$	-	-	2.1
Molecular weight	329.85	g/mol	calculate	2.1
Appearance	White or slightly yellow crystals	-	Visual	2.1
Solubility (20°C)	73	g/100 mL	GB/T 30810-2014	2.1
Melting point (decomposition)	698	°C	DSC	2.3
density	4.18	g/cm^3	Gravity method	2.2
pH (10% solution)	8-9	-	pH Meter	2.3

3.2 Sodium Tungstate Production Process Parameters

parameter	Parameter Value	unit	Process stage	Related Chapters
Alkali dissolution temperature	120-180	°C	High pressure alkali solution	5.2
NaOH concentration	20-30	% w/w	Alkali Dissolution	5.2
Reaction time	2-4	Hour	Alkali Dissolution	5.2
Crystallization rate	0.1-0.5	g/min	Evaporation crystallization	5.3
Energy consumption	500-600	kWh/ton	Hydrometallurgy	16.1
Tungsten recovery rate	>95	%	Ion Exchange	5.6
Wastewater Tungsten Concentration	<0.5	mg/L	Neutralization precipitation	16.2

Performance comparison table of sodium tungstate application fields

Application Areas	Key Performance	Parameter Value	unit	Test Method	Related Chapters
Photocatalysis (WO_3)	Pollutant degradation rate (methylene blue)	>85	%	UV-Vis spectroscopy	9.2
Sodium-ion battery (WO_3)	capacity	300	mAh /g	Constant current charge and discharge	9.3
Electrochromic (WO_3)	Optical modulation rate	70	%	UV-Vis Spectroscopy	10.3
Heavy metal adsorption	Pb^{2+} removal rate	>99	%	ICP-MS	9.1

Antimicrobial coating	E. coli inhibition rate	>80	%	Colony count	8.2
Cemented Carbide (APT)	hardness	>1500	HV	Vickers hardness test	7.1

3.4 Global Sodium Tungstate Market Statistics

index	Parameter Value	unit	years	source	Related Chapters
Global production	5.2	10,000 tons	2024	Industry Estimates	14.1
China's production share	75	%	2024	Industry Report	14.2
Global consumption	4.9	10,000 tons	2024	Market Analysis	14.1
Industrial grade price	22,000-26,000	USD/ton	2024	Trade Statistics	14.4
Analytical grade price	32,000	USD/ton	2024	Trade Statistics	14.4
Average annual market growth rate	4	%	2025-2030	predict	14.1
Recycled tungsten ratio	15	%	2024	Industry Report	16.4

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CTIA GROUP LTD
Sodium Tungstate (Na_2WO_4) Product Introduction

1. Sodium Tungstate Overview

CTIA GROUP Sodium Tungstate (Na_2WO_4, Sodium Tungstate Dihydrate, referred to as ST) is produced using an advanced wet metallurgical process. Na_2WO_4 is a white crystalline powder widely used in catalysis, electroplating, environmental applications, and advanced materials due to its high purity, solubility, and chemical stability. Its tungstate ion (WO_4^{2-}) enables versatile applications in industries ranging from chemical manufacturing to renewable energy.

2. Sodium Tungstate Features

- **Chemical Composition**: $Na_2WO_4 \cdot 2H_2O$, sodium tungstate dihydrate. Purity ≥ 99.9%, with minimal impurities.
- **Appearance**: White or slightly yellowish crystalline powder; orthorhombic crystal structure.
- **High Solubility**: Solubility of 73 g/100 mL in water at 20°C, ideal for aqueous applications.
- **Versatility**: Supports applications in photocatalysis, battery materials, and heavy metal adsorption.
- **Stability**: Chemically stable under dry conditions, with consistent performance in industrial processes.

3. Product Specifications

Type	Particle Size (μm)	Purity (wt%)	Bulk Density (g/cm³)	WO_3 Content (wt%)	Impurities (wt%, max)
Fine Grade	5-10	≥99.9	3.8-4.0	68.00	Fe≤0.001, Mo≤0.002
Standard Grade	10-15	≥99.9	4.0-4.2	68.00	Fe≤0.001, Mo≤0.002
Coarse Grade	15-20	≥99.9	4.2-4.4	68.00	Fe≤0.001, Mo≤0.002

4. Packaging and Quality Assurance

- **Packaging**: Sealed plastic bottles or vacuum aluminum foil bags, net weight 500g, 1kg, or 5kg, ensuring moisture-proof and oxidation-proof storage.
- **Quality Assurance**: Each batch includes a quality certificate with data on purity (ICP-MS), particle size distribution (laser diffraction), crystal structure (XRD), and WO_3 content (titration).

5. Procurement Information

- **Email**: sales@chinatungsten.com
- **Tel**: +86 592 5129595
- **Website**: For more information about sodium tungstate, please visit the China Tungsten Online website (www.sodium-tungstate.com).