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# Tantalum Extraction and Its Wide-Ranging Significance

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## Abstract

*Tantalum is a transition metal with atomic number 73. It has a shiny, silvery-gray appearance and offers a distinctive set of characteristics that give it significant value in a range of applications. Tin is commonly found in association with niobium (Nb) and tantalum (Ta). Cassiterite (SnO2) is the primary tin mineral, typically containing substantial quantities of both niobium (Nb) and tantalum (Ta) compounds. A significant portion of these components are left behind in the slag that is produced at the end of the industrial process, which occurs during the extraction and refining stages of the tin manufacturing process. Those slags are already capable of being considered as a potential and significant source of refractory metals such as tantalum and niobium due to their potential. The mining sector is vital to the nation's gross domestic product (GDP), and tantalum is an important component of that industry. The extraordinary element tantalum is discussed in this abstract, along with its extraction, important properties, and many applications.*

**Keywords**: Tantalum, Niobium, Extraction, Mineral, Tin.

## I. INTRODUCTION

The year 1802 marks the discovery of Tantalum, and the name originates from King Tantalus, a legendary figure in Greek mythology. An very resistant to corrosion metal that is silvery in appearance [1]. In the natural world, tantalum is found on its own on occasion, but in somewhat rare instances. The mineral columbite-tantalite, which contains niobium as well as other metals, is the most prevalent form in which it may be discovered.

Within the process of extracting tantalum from niobium, there are a number of challenging steps that must be completed. The extraction of tin results in the production of a significant quantity of tantalum, which is then distributed for use in commercial applications. Niobium, tantalum, and Rare Earth Elements (REEs) are among the 27 raw commodities that are considered to be of significant importance to the European Union in the year 2017. The reason for this is because these components are necessary for the manufacturing of high-tech products and the development of new technologies. Additionally, the threat that these components represent to supply security and the relevance of these components are also factors that contribute to this situation. Many nations, including as Brazil, China, and Australia, are among those that mine it, as seen in the year-by-year chart [7] (Fig-1). In 2022, it was anticipated that the amount of tantalum produced in the Democratic Republic of the Congo will have reached 860 metric tons, making it the largest tantalum producer in the world by a substantial margin (Fig-2).

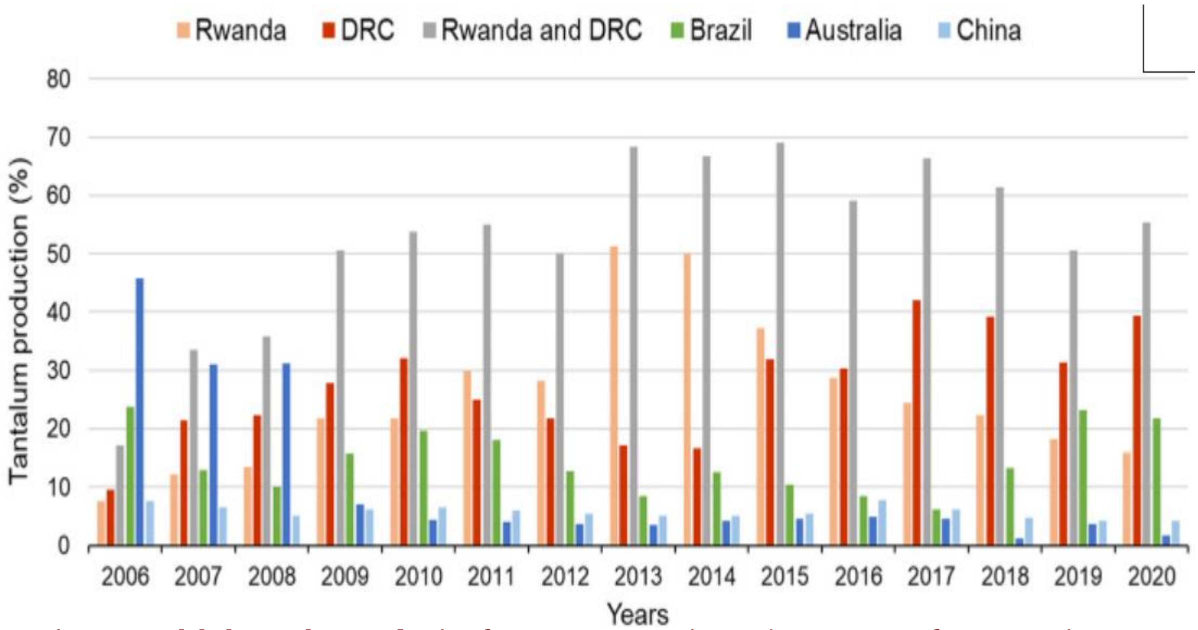


**Figure 1:** ***Global Tantalum production from 2006 to 2020 in metric tons, survey from USGS in 2022.***

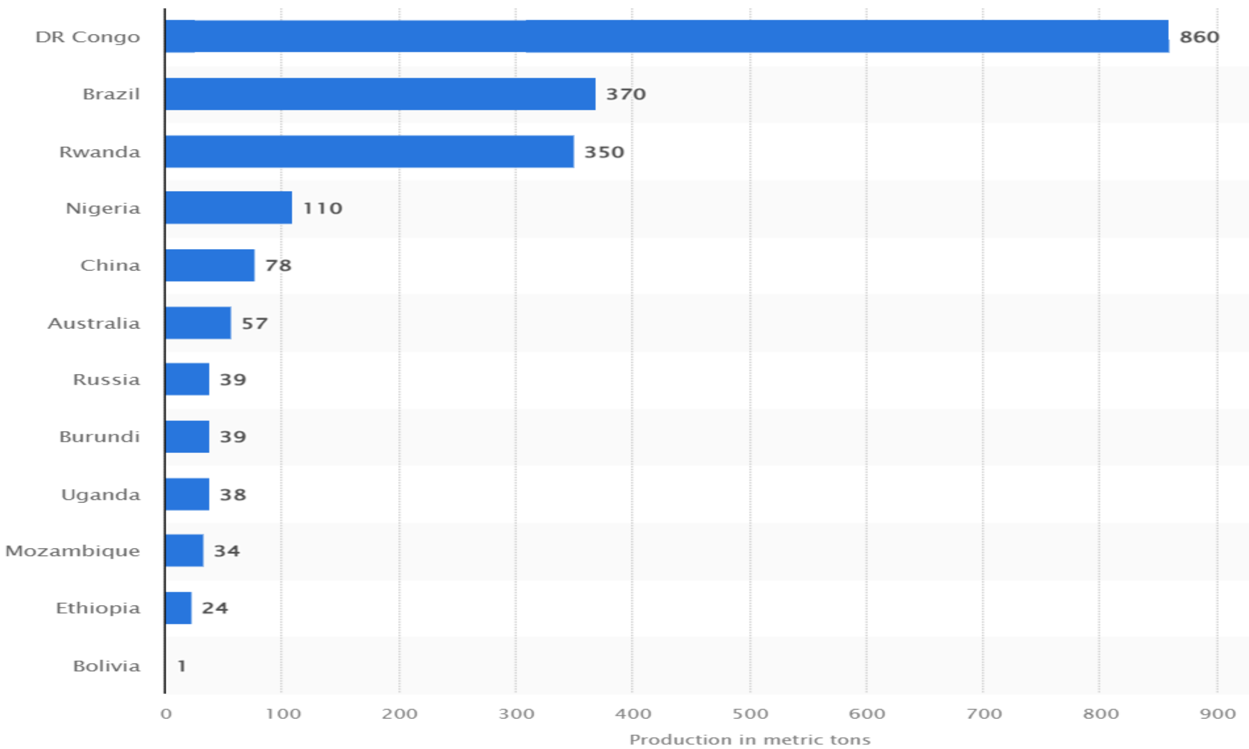


**Figure 2:** ***Global Tantalum production in metric tons in 2022.***

## II. CHEMICAL PROPERTIES:

**Table 1:** ***Various elementary information about Tantalum***

| Element | Tantalum |
|---|---|
| Symbol | Ta |
| Atomic Number | 73 |
| Atomic mass | 180.94788 u |
| Group | 5 |
| Period | 5 |
| Block | D |
| Electronegativity | 1.5 |
| Oxidation states | +3, +4, +5 |

Because of their comparable chemical and physical characteristics, the transition metals niobium and tantalum are nearly always found in pairs in nature. Niobium possesses significant magnetic and superconducting characteristics, in addition to a relatively low density and a high melting point. In addition to its famed resistance to acidic corrosion, tantalum's strong thermal and electrical conductivity makes it an attractive material. It has outstanding qualities that have made it famous, such as:

High melting point: At 3,017 °C (5,463 °F), tantalum ranks as the element with the fifth-highest melting point, after tungsten, rhenium, osmium, and carbon. This renders it well suited for use in settings where temperatures can reach dangerously high levels.

Excellent corrosion resistance: Almost any chemical, including acids, alkalis, and others, will not corrode tantalum. Actually, it is nearly impervious to aqua regia, an acidic liquid that may dissolve platinum and gold, which is a combination of nitric and hydrochloric acids. Because of this, it is very desirable for usage in chemical processing machinery, orthopedic implants, and other fields that demand long-term resilience.

Biocompatibility: Tantalum exhibits biocompatibility, indicating its ability to be well-tolerated by the human body without eliciting undesirable responses. Consequently, this attribute renders it a highly useful substance for medical implants, including dental implants and bone plates.

High ductility and malleability: Tantalum possesses exceptional ductility and malleability, enabling effortless shaping and forming into diverse components.

Density: The density of tantalum, a metal, is 16.69 g/cm$^3$, making it extremely dense.

Boiling point: Tantalum has a melting point of 4,582 °C and a boiling point of 5,458 °C, which is considerably higher.

Hardness: The Mohs hardness scale rates tantalum as 6.5, making it a very hard metal.

## III. EXTRACTION PROCESS

Tantalum is extracted using a number of processes, including mining, concentration, leaching, solvent extraction, and purification are depicts in Fig-3.

The methodology involves the isolation of specific categories of complex ions into aqueous or organic phases in accordance with their respective structures. When dissolved in fluoride solutions, tantalum or niobium produces two distinct classes of complex ions: $TaF_7^{2-}$ and $TaF_6^{-}$, and $NbOF_5^{2-}$ and $NbF_6^{-}$, correspondingly [3].

### 3.1. Mining

Numerous minerals, including tantalite, columbite, columbite-tantalite (Colton), pyrochlore, and euxenite, are used to extract tantalum. Pegmatites, which are igneous rocks that have cooled slowly and produced massive crystals, are usually where these minerals may be found.

A simple and cost-effective technique, gravity separation has long been the gold standard for separating tantalum from its ore. There is a significant difference between this technique and the flotation procedure, as well as the chemical or solvent extraction procedures. There is a significant difference between this method and the substance or dissolvable extraction approach, as well as the buoyancy technique.

### 3.2. Concentration

As soon as the ore is extracted from the ground, it is crushed and powdered into a fine powder. Following this, the powder is processed in order to concentrate the minerals that contain tantalum. This may be accomplished by the use of a wide variety of methods, such as flotation, gravity separation, and magnetic separation.

### 3.3. Leaching

Subsequently, a solution consisting of hydrofluoric acid (HF) and sulfuric acid (H2SO4) is used in order to leach the minerals that contain concentrated tantalum. The solution dissolution of tantalum and niobium, which is usually found in association with tantalum, is the outcome of this process.

### 3.4. Solvent extraction

Following that, the tantalum and niobium solution is separated from the remaining impurities by the use of solvent extraction and separation. To do this, an organic solvent is added to the mixture in order to separate the tantalum and niobium from the rest of the components. In the next step, the solvent and the solution are separated, and then the tantalum and niobium are extracted from the solvent.

The separation and purification of niobium and tantalum are both accomplished by the use of solvent extraction in industrial procedures. During these processes, fluoride is present in order to enable the production of fluoro-complexes, which are compounds that are capable of combining with organic molecules [4].

### 3.5. Purification

Following this, the tantalum and niobium are purified by the processes of precipitation and filtering. Tantalum pentoxide, also known as $Ta_2O_5$, is the final product, and it is a powder that is white in color [5].

### 3.6. Reduction

During the following step, the electrolysis of sodium or fused salt is used in order to achieve the reduction of tantalum pentoxide to metallic tantalum. The metallic tantalum is then subjected to further processing in order to generate a number of forms, including powder, wire, and sheet, once this phase has been completed.

The extraction of tantalum is a hard process that takes a substantial amount of energy to complete. In spite of this, the production of tantalum that is of a high purity is required for a broad range of applications, such as the production of medical implants, electrical components, and a variety of capacitors.

There has been a significant amount of research conducted on the liquid-liquid extraction (LLE) of tantalum from solutions that include fluoride and sulfuric acid, using 2-octanol as the solvent. Using two different solutions that were produced from tantalum or tantalite scrap, the best process factors were established and analyzed. These variables included the temperature, the acidity of the initial solution, and the mixing time of the phases.

Niobium and tantalum are in the same group (VB) on the periodic table, which makes it difficult to differentiate between the two elements due to the fact that they share many chemical features for which they are shared. The majority of the time, these metals may be recovered from raw materials by using hydrometallurgical processes. For the manufacturing of pure tantalum and niobium, the Mariganec process, which was a crystallization method that required more effort and was less effective, was replaced by techniques that included solvent extraction (SX).

As a result of increasingly stringent regulations aimed at protecting human health and the environment, harmful fluorides are required to be substantially reduced or eliminated entirely. In light of this, there is an immediate need for the development of innovative chemical and aqueous techniques for the separation and purification of tantalum and niobium.

In the majority of instances, the end products of converting tantalum values in solution are either potassium tantalum fluoride ($K_2TaF_7$) or tantalum oxide ($Ta_2O_5$). By first neutralizing the niobium fluoride complex with ammonia, which results in the generation of hydroxide, and then calcining the process to create oxide, it is feasible to recover niobium as niobium oxide ($Nb_2O_5$). This is a procedure that may be carried out. It is possible for compounds that include niobium and tantalum to have a wide range of valences, including +5, +4, +3, +2, and even + 1. Nb(V) and Ta(V) are the only stable states that may exist in solution without any other states. Utilizing reducing reagents such as amalgam, cadmium, zinc, or aluminium, it is not feasible to get Ta(V) down to its lower valence state with any of these substances.

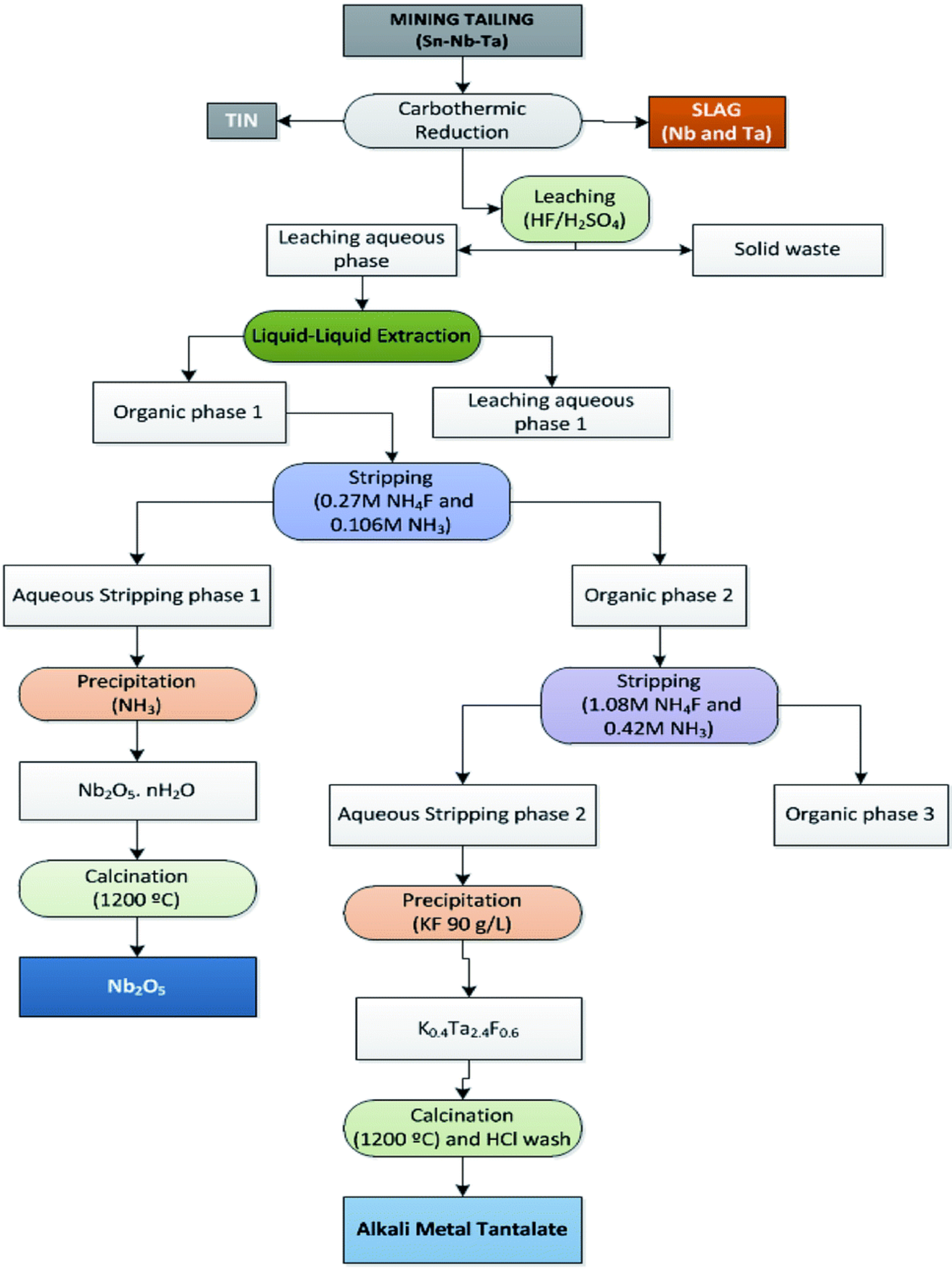


**Figure 3:** *Extraction flow chart*

## IV. ANALYSIS

Due to the fact that the chemical characteristics of niobium and tantalum are quite similar to one another, the determination of these elements through the use of chemical techniques was fraught with numerous challenges. Because of this, the analytical processes that were used to determine the presence of these components in the samples that were used for study and/or manufacturing were often difficult, requiring the use of costly reagents and a significant amount of time.

## V. EXPERIMENTAL THEORETICAL BACKGROUND-ICP-OES

Inductively coupled plasma optical emission spectrometry is a potent source of atomic and ionic emission that may be exploited mainly for quantitative multi-element analysis of the majority of various kinds of materials, with the exception of argon and helium. This technique is a powerful source of emission that can be used for a wide range of applications. Due to the fact that it allows for the study of both major and trace elements from a single sample, the technique is appropriate. Because of the technique's wide dynamic range, this is now within the realm of possibility. When utilizing an ICP-OES, it is not feasible to detect some elements in a comfortable way unless additional specific changes are made to the apparatus [6].

In the process of doing an ICP-OES analysis, it is common practice to employ a stream of liquid to transport the sample into the instrument. Through a process known as nebulization, which takes place within the device, the liquid is converted into an aerosol. This process is responsible for the transformation. Following that, the sample aerosol is transported to the plasma, where it is subjected to a number of changes. These transformations include the sample aerosol being vaporized, atomized, desolvated, stimulated, and/or ionized on account of the plasma. In order to collect the radiation that is released by excited atoms and ions, which discharge their own distinct radiation, a device that categorizes the radiation according to wavelength is used. After the radiation has been detected, it is then converted into electrical signals so that the analyst may get information about the concentration of the radiation. The illustration in Figure 3 depicts a typical ICP-OES apparatus.

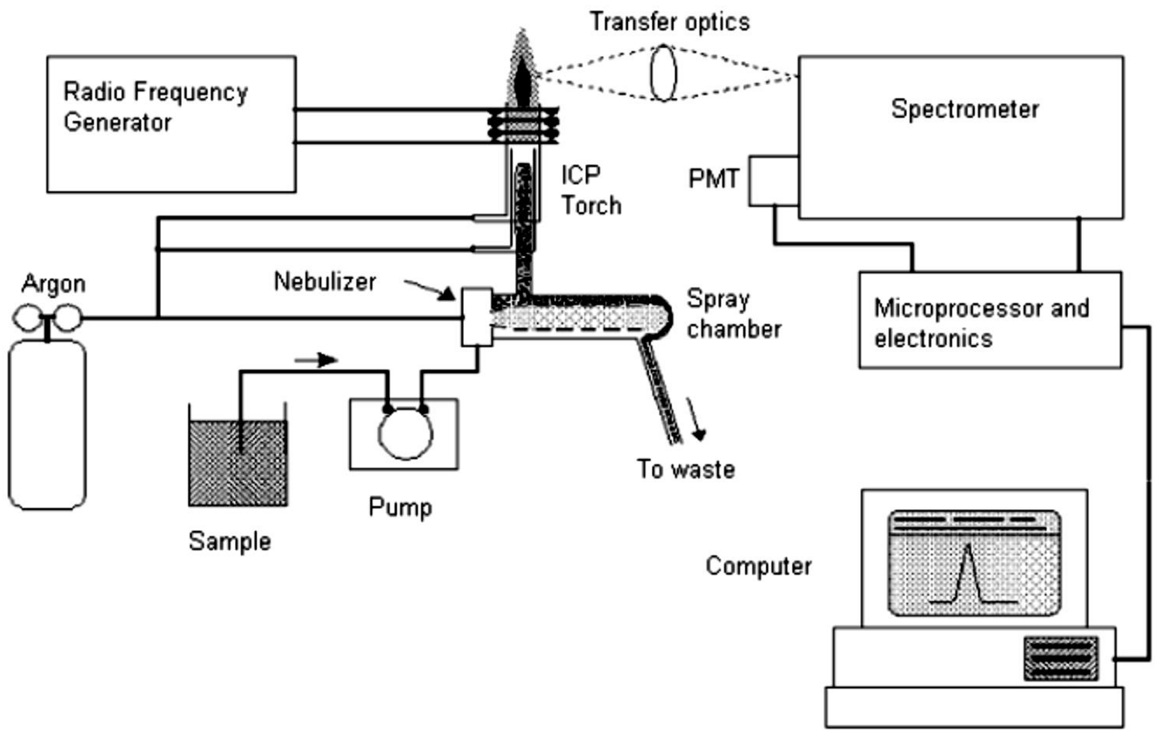


**Figure 4:** ***ICP-OES***

## VI. APPLICATIONS

Tantalum possesses a distinctive blend of characteristics, making it very versatile and applicable in several sectors, such as:

Electronics: Tantalum is a crucial substance used in the manufacturing of electronic capacitors, namely tantalum capacitors. These capacitors are extensively utilized in diverse electronic products, including smartphones, digital cameras, and laptops, owing to their notable capacitance, compact dimensions, and extended durability [2]. Each mobile phone contains a mere 40 milligrams of tantalum. However, considering the present ratio of two phones per three persons on Earth, the total amount of tantalum becomes significant. Over 2.5 million kg were utilized last year, with two-thirds of that amount being allocated to electronic gadgets.

Aerospace: The high melting point and good strength of tantalum make it useful in a number of aeronautical applications. Blades for jet engines, nozzles for rockets, and thermal protection systems are some of its components.

Chemical processing: Chemical processing equipment especially that which deals with extremely corrosive chemicals, might benefit greatly from tantalum's extraordinary corrosion resistance. It finds application in machinery including pumps, heat exchangers, and reactors.

Medical: Because of its low toxicity and high biocompatibility, tantalum has several medicinal applications. Dental implants, bone plates, and surgical tools are just a few of the medical implants that employ it.

Other applications: Tantalum is utilized in many purposes, including jewellery, ornamental coatings, and scientific apparatus. Tantalum is employed in composites and wires, precise instruments, reaction vessels and funnels, ultra-high frequency electron tubes, lenses, vacuum heater components, timepieces, and as a platinum alternative in capacitors due to its chemical inertness.

## VII. CONCLUSION

Tantalum is a very adaptable and precious metal that possesses distinctive qualities, rendering it indispensable for a diverse array of uses in several sectors. The expansion of the demand for tantalum on the market is defined in terms of the raw tantalum materials that are required to fulfill the market's requirements. Ongoing research is being conducted to discover alternative materials and enhance the efficiency of tantalum extraction and processing, due to the limited supply and growing demand for it.

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### Conflicts of Interest

The authors declare no conflict of interest.

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