FEBRUARY 2024

RARE EARTH CRITICAL MATERIALS

CSS DIALOGUE REPORT

THE CENTRE FOR SECURITY STUDIES

RARE EARTH ELEMENTS

This report is about Rare Earth Elements (RREs), which consist of seventeen metallic elements that play a crucial role in many high-tech devices. These elements are also called Rare Earth Oxides, as most of them are usually sold as oxide compounds. Currently, China is the largest producer of these rare earth elements.

The aim of this report is to analyse some of the Rare Earth Elements such as Cerium, Dysprosium, Europium, etc. Each element is examined based on its availability, applications, extraction and production methods, environmental effects, and more. In recent years, the demand for these elements has increased rapidly due to their critical importance in various technologies. They are particularly essential for producing high-performance magnets used in electric vehicle motors, wind turbines, and military equipment. Despite their significance in modern industry, the exploration, extraction, and sustainable use of REEs present significant challenges. This report also analyses some of the challenges involved in the use of REEs.

This report, divided into 3 parts, is the work of 9 Research Interns at CSS. They have researched rare earth elements that play a crucial role in modern technologies such as clean energy. It aims to provide valuable insights and perspectives to deepen our understanding of these elements.

This report is a product of the Centre for Security Studies, Jindal School of International Affairs.

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TERBIUM

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Abstract

The presentation on terbium provides a complete review of this rare earth metal, concentrating on its history, major features, industrial and technical uses, current research trends, and environmental consequences. Through a thorough examination of terbium, the audience will get significant insights into its discovery, unique features, numerous industrial applications, current study topics, and environmental consequences. The presentation aimed to offer a comprehensive overview of terbium, throwing light on its importance in numerous disciplines and possibilities for future advances. This report will serve as a complete summary of the presentation's important points, providing a great resource for future research and study of terbium and its various uses.

Introduction

Terbium is a rare earth metal with a silvery-grey appearance that is well-known for its rare qualities and wide range of uses in numerous sectors. It is malleable, ductile, and extremely stable in air, making it a critical component in a wide range of technologies.[1] Terbium's capacity to generate 3+ and 4+ ions result in high paramagnetism and antiferromagnetic characteristics within certain temperature ranges.[2] This rare earth element is essential in the creation of phosphors for lighting, television displays, and monitors. Its importance extends to the production of magnets for electric motors and wind turbines, metallic films for magneto-optic data recording, and as a dopant for solid-state electronics and optical fibres.[3]

The sole isotope found in ores is terbium-159. Terbium has 36 radioactive isotopes (excluding nuclear isomers). Their masses vary from 135 to 171, and their half-lives range from more than 200 nanoseconds (terbium-138) to 180 years (terbium-158).[4]

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[1] "Terbium - Element Information, Properties and Uses: Periodic Table," Terbium - Element information, properties and uses | Periodic Table, accessed January 15, 2024, https://www.rsc.org/periodic-table/element/65/terbium. 1. "Terbium - Element Information, Properties and Uses: Periodic Table," Terbium - Element information, properties and uses | Periodic Table, accessed January 15, 2024, https://www.rsc.org/periodic-table/element/65/terbium.

[2] *Ibid*.

[3] Ibid.

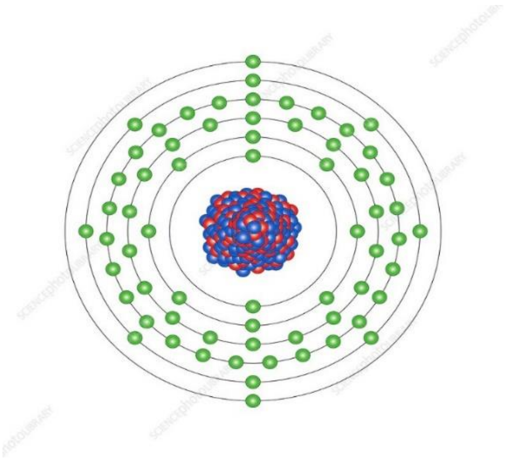
[4] Ibid.

History

The name is derived from the village of Ytterby in Sweden,[5] where the mineral ytterbite (the source of terbium) was originally discovered. Carl-Gustav Mosander, a Swedish physician and scientist, found terbium in a yttrium salt in 1843 and separated it into three elements.[6] He named one yttrium, terbium, a rose-coloured salt, and erbium, a dark yellow peroxide.

In 1862, Swiss scientist Marc Delafontaine re-examined yttrium and discovered yellow peroxide. Because the rose-coloured oxide was now known as erbium, he renamed the yellow peroxide terbium.[7] As a result, the original designations for erbium and terbium samples have been swapped.

Properties



The atomic weight of terbium is 158.92535[8] as determined by the U.S. Department of Energy, and its electronic configuration is $[Xe]6s^2 4f^9$.[9] Its Van der Waals atomic radius is measured at 221 pm (Van der Waals),[10] its empirical atomic radius is measured at 175pm (Empirical),[11] and its covalent atomic radius is measured at 194(5) pm (Covalent).[12]

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[5] Ibid.

[6] Ibid.

[7] Ibid.

[8] "It's Elemental." It's Elemental - The Element Terbium. Accessed January 16, 2024. https://education.jlab.org/itselemental/ele065.html.

[9] Periodic Table of elements: Los Alamos National Laboratory, accessed January 16, 2024, https://periodic.lanl.gov/65.shtml.

[10] Periodic Table of elements: Los Alamos National Laboratory, accessed January 18, 2024, https://periodic.lanl.gov/65.shtml.

[11] "NLM Web Policies," U.S. National Library of Medicine, accessed January 16, 2024, https://www.nlm.nih.gov/web_policies.html#copyright.

[12] Ibid.

Terbium reacts with nitrogen, carbon, sulphur, phosphorus, boron, selenium, silicon, and arsenic at high temperatures to generate a variety of binary compounds, including TbH2, TbH3, TbB2, Tb2S3, TbSe, TbTe, and TbN.[13] In such compounds, Tb is typically in the +3-oxidation state and occasionally +2. Terbium(II) halides are formed by annealing Tb(III) halides in the presence of metallic Tb in tantalum containers.[14] Terbium's boiling point is around 3503 Kelvin (K), which is similar to 3230 degrees Celsius (°C) or 5846 degrees Fahrenheit (°F)[15] and the melting point is approximately 1629 Kelvin (K), which is equivalent to 1356 degrees Celsius (°C) or 2473 degrees Fahrenheit (°F).[16]

Terbium exists naturally as a single stable isotope, terbium-159. This makes terbium mononuclidic and monoisotopic. However, thirty-six radioisotopes of terbium have been identified. The largest of them is terbium-171, with an atomic mass of 170.95330(86) u, while the lowest is terbium-135, whose precise mass is unknown. Terbium's most stable synthetic radioisotopes are terbium-158 (half-life 180 years) and terbium-157 (half-life 71 years). These isotopes survive longer than others. On the other hand, the other radioactive isotopes of terbium have substantially shorter half-lives, with the bulk lasting less than a quarter of a year. Many of them have half-lives of less than half a minute. Electron capture is the principal decay process that occurs before reaching the most prevalent stable isotope, terbium-159. The decay process produces gadolinium isotopes. After reaching terbium-159, the primary decay mode is beta-minus decay, which produces dysprosium isotopes.

Terbium contains 27 nuclear isomers, ranging in mass from 141 to 154, 156, and 158. It is worth noting that not all mass numbers correlate to a single isomer. The most stable isomers are terbium-156m and terbium-156m2, which have half-lives of 24.4 and 22.7 hours, respectively. Interestingly, these isomers have longer half-lives than the ground states of most radioactive terbium isotopes, except for those with masses ranging from 155 to 161. This displays the relative stability of these specific nuclear isomers in terms of terbium isotopes.

Production

Crushed materials containing terbium are processed with highly concentrated sulfuric acid to make water-soluble rare earth sulphates. The acidic filtrates are partially neutralised with caustic soda to a pH of 3-4. Thorium precipitates out of the solution as hydroxide and is eliminated. The solution is then treated with ammonium oxalate, which converts rare earths into insoluble oxalates. Heating causes oxalates to break down into

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[13] Pradyot Patnaik, *Handbook of Inorganic Chemicals* (New York: McGraw-Hill, 2003).

[14] "It's Elemental." It's Elemental - The Element Terbium. Accessed January 16, 2024. https://education.jlab.org/itselemental/ele065.html.

[15] Ibid.

[16] Ibid.

oxides. The oxides are dissolved in nitric acid, which eliminates one of the primary components, cerium oxide, which is insoluble in HNO3. Terbium is isolated as a double salt with ammonium nitrate by crystallisation.[17]

Ion exchange is the most effective method for separating terbium salt from a rare-earth salt solution. Rare-earth ions are sorbed onto an appropriate ion-exchange resin by exchange with hydrogen, ammonium, or cupric ions contained in the resin.[18] The rare earth ions are then selectively rinsed away using appropriate complexing agents. Terbium metal, like other rare earths, is created by reducing anhydrous chloride or fluoride with calcium metal. Vacuum remelting, distillation, amalgam formation, and zone melting are all methods for removing calcium and tantalum impurities.[19]

Extraction

Terbium may be extracted from the minerals monazite and bastnaesite via ion exchange and solvent extraction. It is also derived from euxenite, a complex oxide containing 1% or more terbium.[20] The metal is often manufactured commercially by reducing anhydrous fluoride or chloride with calcium metal in a vacuum.[21] The metal can also be produced by the electrolysis of terbium oxide in molten calcium chloride. It is also present in the product of nuclear fission. Terbium is one of the rare earths with the lowest quantity in the Earth's crust, about equal to thallium.[22]

Terbium does not have any direct high-grade ores; instead, it is found as a very tiny ingredient in rare-earth minerals. Terbium oxide, for example, makes up barely 0.01% of the bastnaesite in California. 0.05-0.16% of Florida's monazite, and around 1.00% in Malaysian xenotime. Currently, the most commercially important rare-earth-containing minerals are bastnaesite (California), monazite (Florida, Australia, India, and China), and xenotime (Malaysia).[23]

The extraction of high-purity terbium metal requires many significant procedures. They

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[17] Ibid.
[18] Ibid.
[19] Ibid.
[20] "Terbium - Element Information, Properties and Uses: Periodic Table," Terbium - Element information, properties and uses | Periodic Table, accessed January 16, 2024, https://www.rsc.org/periodic-table/element/65/terbium#:~:text=Terbium%20can%20be%20recovered%20from,calcium%20metal%2C%20under%20a%20vacuum.
[21] Ibid.
[22] Ibid.
[23] YOSRY ATTIA, "Extraction and Refining of High Purity Terbium Metal From Rare Earth Resources," Taylor and Francis Online , April 2, 1990, https://www.tandfonline.com/doi/pdf/10.1080/08827509008952668#:~:text=EXTRACTION%20OF%20TERBIUM%20BY%20CONVENTIONAL,sarnarskite%2C%20euxenite%20and%20monazite.%20.&text=YTTERBIUM%20(Yb).,THULIUM%20(Tm).

are,

(1) Recovery of rare earth minerals from ores into REO concentrates.[24]

(2) Exploration efforts are carried out to locate locations with commercially feasible concentrations of rare earth elements, such as terbium.[25]

(3) Mining activities extract terbium-containing ore from the Earth's crust. Rare earth element-rich ores are usually found in conjunction with minerals such as bastnäsite, monazite, or xenotime.[26]

(4) Beneficiation methods extract valuable minerals from gangue, or undesirable material, in mined ore. Various processes, such as crushing, grinding, and gravity separation, can be used.[27]

(5) Leaching rare earth metals (REM) into leach solutions. This procedure is frequently preceded by a roasting step and a little leaching to eliminate related carbonates.[28]

(6) Separation or concentration of rare earth metals into groups or individual metal solutions using solvent extraction and/or ion exchange. Terbium precipitates out from the solvent extraction solution as oxalate or carbonate compounds, which are transformed into terbium oxide when heated in the air.[29]

(7) Additional purification processes may be required to eliminate contaminants and produce high-purity terbium.[30]

Uses of Terbium

(1) Rare earth elements are extensively used in the production of electronics such as cell phones, laptops, and flat-screen displays. Terbium, in particular, is used in the manufacture of phosphors for colour television tubes and LED lighting. Its green emission is useful for creating green colours in display technology.[31]

(2) Neodymium-iron-boron magnets, which frequently contain terbium, are required for the manufacture of strong and lightweight magnets used in electric car motors, wind turbines, and other industrial uses. Terbium is especially employed to

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[24] Ibid.
[25] Ibid.
[26] Ibid.
[27] Ibid.
[28] Ibid.
[29] Ibid.
[30] Ibid.
[31] "Terbium - Element Information, Properties and Uses: Periodic Table," Terbium - Element information, properties and uses | Periodic Table, accessed January 16, 2024, https://www.rsc.org/periodic-table/element/65/terbium#:~:text=Terbium%20can%20be%20recovered%20from,calcium%20metal%2C%20under%20a%20vacuum.

improve the performance of these magnets by increasing the temperature stability and coercivity of the material.[32]

(3) Terbium catalyses a variety of chemical reactions. It helps in refining petroleum, providing clean fuels, and facilitating chemical reactions in industrial processes.[33]

(4) The strategic importance of a rare earth element can be understood through its use and role in defence and national security applications. Terbium is also used in the manufacturing of advanced military technologies and equipment, such as missile guidance systems, radar systems, and other communication equipment. Terbium's ability to absorb neutrons enables it to be used in control rods for some nuclear reactors since it helps regulate the nuclear fission process.

(5) Terbium also plays an important role in the medical industry. It is used in certain medical lasers and diagnostic tools. It also has potential utilisation in medical imaging, especially in developing contract agents for MRI (magnetic resonance imaging).[34]

(6) Presently, terbium is being investigated and looked into as an option for potential usage in the development of certain types of solar cells.[35]

(7) Finally, terbium is employed in a variety of research and development activities, including materials science and electronics, to investigate its unique features and possible uses.

Rare earth element manufacturing and production have historically been dominated by China, which has led to worries about supply chain vulnerabilities. Based on the multiple uses highlighted above, efforts are being undertaken internationally to diversify suppliers and develop alternative technologies to reduce reliance on a single supplier or manufacturer.

The application and use of terbium are highly dependent upon its specific properties, like magnetism and optical elements. With the advancement of technology, there has been a discovery of newer applications for terbium and other rare earth elements. The same is only bound to increase. However, at the same time, efforts are underway to reduce dependency on such elements due to concerns about their limited supply and environmental impact.

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[32] Ibid.

[33] Ibid.

[34] Ibid.

[35] Eitpl, "Why Are Rare Earth Elements so Crucial for Electronics Manufacturing?," East India Technologies, October 3, 2019, https://eitplems.com/why-are-rare-earth-elements-so-crucial-for-electronics-manufacturing/.

Purification of Terbium

The level of purification of terbium is largely dependent upon the mode of extraction and refining processes used. Purification is done based on the quality standards required for its application.

Terbium in the form of terbium oxide (Tb_2O_3) is usually used for industrial processes. High-purity terbium oxide is typically used in electronics, optics, and other advanced technologies.[36] The degree of its purity is often expressed based on the percentage of total terbium present.

For example,

(1) Terbium oxide with a purity of 99.9% (3N) or higher is used for scientific research or in laboratory settings.[37]

(2) Commercially available terbium oxide is generally of a purity level of 99.99% or higher (4N).[38]

(3) Ultra-pure terbium with a purity of 99.999% (5N) or greater may be used for certain specialised applications, like the production of high-performance magnets of specific electronic components.

Challenges and Considerations

Terbium has numerous valuable properties, as discussed; however, the use of this element is not without its challenges. Its versatile application faces challenges such as dependence on the global supply chain, impact on the environment, high production costs, geopolitical concerns, and limited public awareness.

(1) The bulk of terbium and other rare earth elements are frequently concentrated in a few geographical areas, raising worries about global supply chain vulnerabilities. Efforts to diversify sources and lessen reliance on certain locations are critical for a robust supply chain.

(2) Mining and the extraction of terbium can have an environmental impact. Soil and water pollution can occur as a result of mining and refining activities, and the creation of radioactive waste presents environmental difficulties. To offset these effects, rare earth element producers must adopt sustainable and ecologically acceptable procedures.

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[36] Ibid.

[37] American Elements, "Terbium(III,IV) Oxide," American Elements, June 13, 2017, https://www.americanelements.com/terbium-iii-iv-oxide-12037-01-3.

[38] Ibid.

(3) The extraction and separation of rare earth elements are difficult and resource-intensive operations, which contribute to increased costs. Finding cost-effective technologies and investigating recycling programmes are two areas of continuing study to make rare earth elements more economically feasible.

(4) The geopolitical situation can influence the availability and price of rare earth materials. Efforts to lessen reliance on certain nations, such as China, or areas for terbium sourcing are critical for reducing geopolitical concerns.

(5) Terbium and the problems connected with its production are frequently underappreciated by the general population. Increased awareness is critical for promoting responsible consumption, recycling, and sustainable sourcing.

Conclusion

Finally, terbium's distinctive features, such as luminescence and magnetic strength, position it as a vital participant in a variety of sectors. While its uses in lighting, electronics, and medical imaging demonstrate its flexibility, the paper also highlights considerable hurdles. The global supply chain's reliance on restricted geographic sources raises hazards, demanding measures to diversify and assure a consistent supply. Environmental issues necessitate sustainable techniques in terbium extraction and processing, emphasising the necessity of responsible mining and waste management. High manufacturing costs and geopolitical concerns emphasise the importance of strategic planning and collaborative activities.

Moving forward, it is critical to investigate alternate technologies and raise public awareness about the importance of rare earth elements. Addressing these difficulties needs a multifaceted strategy that includes governments, industry, and researchers. Sustainable practices, recycling programmes, and technological advancements will all play important roles in determining the responsible future usage of terbium. As we negotiate the complex world of rare earth elements, it becomes clear that combining technological achievements with environmental and geopolitical concerns is critical for ensuring a robust and sustainable future. Terbium, with its distinct qualities, lies at the crossroads of innovation and responsibility, encouraging stakeholders to embrace ethical behaviours for peaceful cohabitation with our planet.

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URANIUM

Shashwat

Abstract

The exceptional characteristics and critical importance of uranium in various sectors, particularly energy production, have garnered considerable interest in it. This study thoroughly examines the multifaceted nature of uranium, encompassing its historical background, source, geological location, market value, current applications, and potential future uses. This analysis is based on a wealth of research and data to present a thorough scientific and economic picture of uranium. The significance of uranium concerning new technologies, healthcare, and nuclear power is underscored through an examination of its historical background, present condition, and position in global commerce. The research investigates the intricate processes involved in uranium mining, extraction, and purification. Additionally, it assesses the impact of advanced technologies such as data mining and artificial intelligence on optimising exploration efficiency. Additionally, the article explores the subject of uranium's economic value augmentation via mineral blending, with a particular emphasis on technological synergies, enhanced extraction efficiency, strategic mineral supply chains, and diversification. The article explores the geopolitical and regional ramifications of mixed-mineral deposits, emphasising their impact on global mineral supply dynamics, regional economic development, and social and environmental conditions. In conclusion, the study emphasises the significance of considering environmental and social factors alongside economic ones when administering resources. As an illustration of the heterogeneous nature of the contemporary mining industry, the complex interaction between uranium and other minerals requires interdisciplinary approaches to resource management that are both environmentally and ethically sound.

Introduction

The radioactive properties of uranium, an element that occurs naturally, are widely recognised. Its atomic number is 92, and its chemical symbol is U. The speculative implications regarding nuclear power and nuclear weapons have captured the interest of individuals globally. Uranium is crucial to the development of environmentally sustainable and efficient energy sources for the future of electricity generation. In this study, uranium is examined in great detail, from its definition to its numerous applications. Unique opportunities exist to increase the monetary value of natural resources due to the presence of uranium in geological formations alongside other contemporary minerals. An effort is made to comprehend the geostrategic ramifications of uranium's combination with other minerals in this research. The investigation entails an examination of the geological factors that influence uranium amalgamation, the economic advantages of combining to increase value, and the broader geopolitical context that shapes the mining environment.

Identity: Uranium, which belongs to the actinide series, is a massive, silvery-white metal. It comprises three uranium isotopes, denoted as U-238, U-235, and U-234. The predominant isotope of uranium discovered in the natural world is uranium-238 (U-238), comprising over 99 percent of the total. Despite its scarcity, the isotope uranium-235 (U-235) is significant because it can sustain a nuclear chain reaction. U-235 is in high demand for nuclear energy and the production of nuclear weapons on account of this characteristic (Pastoor, K. J., Kemp, R. S., Jensen, M. P., & Shafer, J. C., 2021). One of the elements, U-235, distinguishes itself as an essential constituent of nuclear reactors and weaponry due to its exceptional capability of maintaining a nuclear chain reaction.

Modern Applications of Uranium

Nuclear Power: The generation of nuclear power is currently the primary use of uranium. The heat produced during the nuclear fission process within nuclear reactors is subsequently converted into electrical energy. In an effort to reduce their environmental influence, an increasing number of countries are adopting nuclear energy as a cleaner alternative to fossil fuels.

Medical Application: Uranium isotopes have both therapeutic and diagnostic applications in the medical field. Brachytherapy, an instance of a cancer treatment method, employs uranium-238 as its radiation source. In addition, imaging techniques used in kidney and bone examinations involve uranium compounds (Yan, H., Liu, X., Zhang, F., Ma, K., Shao, X., Wu, F., ... & Hu, S, 2022).

Uranium-235 is a critical component in the production of nuclear weapons, fulfilling a military function. The fissile characteristics of this isotope enable the construction of atomic bombs with exceedingly destructive potential. While the military applications of uranium demonstrate its versatility, they also give rise to ethical concerns.

Prospective Applications of Uranium in the Future

Advanced Nuclear Reactors: Ongoing investigations explore contemporary reactor designs, including fast breeder and thorium-based reactors, to enhance waste management, safety, and efficiency. These developments, which may position uranium as a fundamental component for sustainable power generation in the future, possess the capacity to significantly transform the landscape of nuclear energy.

Space Exploration: Uranium possesses the potential to be used in nuclear propulsion systems, thereby supplying power for expeditions to extreme depths in space. Due to its extended duration of energy production, uranium is a viable option for propulsion in spacecraft undertaking lengthy journeys (Kolhe, N., Damle, E., Pradhan, A., & Zinjarde, S, 2022).

Desalination:_Utilising the heat-generating properties of uranium in the desalination process could assist in alleviating the global water shortage. Some regions are experiencing severe water shortages; by supplying nuclear energy to desalination units, uranium could assist in mitigating this issue.

Origin of Uranium

The origin of uranium can be attributed to both galactic and primordial epochs. In the nascent stages of the universe, primordial uranium, which comprises U-238, U-235, and U-234, was generated. Cosmogenic uranium is an additional component of the Earth's uranium stockpile; it is generated via interactions with cosmic radiation.

Primordial Origin: Uranium was simultaneously formed with the universe, providing it with a primordial beginning. The generation of heavy metals, such as uranium, is attributed to nucleosynthesis, a process that takes place during supernova explosions (Jyothi, R. K., De Melo, L. G. T. C., Santos, R. M., & Yoon, H. S, 2023). The components from which our solar system and Earth originated comprised these elements, which were subsequently expelled into space.

Radioactive Decay: Radioactive decay is a prevalent phenomenon involving uranium, which occurs over extended periods of geological time due to its radioactive nature. The isotopes U-238 and U-235 hold the utmost significance. U-238, which is more abundant, undergoes an extensive degradation process before achieving stability as lead-206. A shortened decay chain, on the other hand, is what causes the transformation of U-235 to lead-207 (Chen, T., Yu, K., Dong, C., Yuan, X., Gong, X., Lian, J., ... & Wang, X, 2022).

Geological Processes: Following geological processes, the uranium distribution in the Earth's crust is not uniform. While uranite is the most common mineral to contain it, it is also found in numerous others. Numerous geological processes, including magma solidification and cooling, mineral concentration in ore deposits, and attrition, contribute to the distribution and concentration of uranium.

Mining: Humans extract uranium through the mining of ores containing uranium minerals. Predominant uranium ores consist of pitchblende, uraninite, and carnotite. Mining processes extract these ores from the Earth's crust for an array of purposes, including the production of nuclear fuel.

Occurrence of Uranium

Uranium Deposits: Varying concentrations of uranium are found in the Earth's crust, with certain geological formations harbouring a greater abundance of this element than others. Namibia, Australia, Canada, and Kazakhstan are among the most significant uranium producers on the globe. The extraction of uranium necessitates strict adherence to safety protocols and increased environmental awareness due to the mining and milling processes involved (Costa Peluzo, B. M. T., & Kraka, E, 2022).

Secondary Sources: After primary deposits, secondary sources comprise uranium obtained through the extraction of byproducts from the mining processes of other minerals, such as phosphate and copper. As a result of nuclear fuel reprocessing and recycling, more uranium is accessible for commercial use.

Resale Value of Uranium

Uranium Market Dynamics: Diverse energy demands, global geopolitical events, and modifications in nuclear policy are a few of the elements that influence the uranium market. The resale value of uranium is influenced by market fluctuations, which subsequently impact the economic viability of uranium mining and exploration.

Uranium Spot Prices: Standard uranium trading practices include market prices and long-term contracts. The current spot price of uranium is determined by market forces, including geopolitical unpredictability and elements of supply and demand. It is imperative that all stakeholders in the nuclear industry, including investors, possess a comprehensive understanding of these fluctuations in prices.

Investment Opportunities: Increasing investment in uranium mining companies has resulted from developments in reactor technology and a growing interest in nuclear power. Investors consider uranium to be a substantial commodity within the dynamic global energy market, especially those with a strong interest in energy transition and sustainable practices.

The Uranium Mining Sector: Key Participants and Locations

Local populations, mining companies, governmental bodies, and regulatory organisations are all interconnected elements within the uranium extraction network. Prominent uranium reserves are situated in countries such as Australia, Canada, Kazakhstan, and Namibia, albeit with an irregular distribution across the globe (Surdyk, S., Itani, M., Al-Lobaidy, M., Kahale, L. A., Farha, A., Dewachi, O., ... & Habib, R. R, 2021). Prominent mining companies such as Cameco and Areva are attracted to the Athabasca Basin in Canada due to the abundance of high-grade uranium resources located within the region. Several components must function in concert throughout the extraction procedure. Governments bear the primary responsibility for ensuring adherence to international nuclear non-proliferation treaties, environmental safety standards, and regulations governing uranium mining. On the contrary, mining companies engage in partnerships with governmental entities to access and utilise uranium reserves ethically by supporting exploration, extraction, and processing technologies.

Methods of Extraction for Uranium

Underground mining and open-pit mining are the two primary methods used to extract uranium. When uranium resources are near the Earth's surface, open-pit mining is employed to facilitate mining processes. However, much of the burden that this procedure eliminates causes people to be concerned about the environment. In contrast, underground mining involves the construction of subterranean passages to gain access to uranium ore deposits situated at greater depths. Although this method raises concerns regarding safety and cost, it is significantly less detrimental to the environment. Economic viability, geological variables, and ore grade are some of the factors considered when determining which of these processes to implement (Surdyk, S., Itani, M., Al-Lobaidy, M., Kahale, L. A., Farha, A., Dewachi, O., ... & Habib, R. R, 2021).

Data Mining in Uranium Exploration

In uranium exploration, sophisticated techniques are employed to accurately identify potential resources. Data mining utilising satellite images and geological surveys is the initial step of this process. Geologists use data obtained from geological surveys, which furnish critical insights into the Earth's crust, to identify regions characterised by elevated uranium quantities. Using satellite imagery from a bird's-eye view can locate surface features associated with uranium resources. The integration of these datasets enables researchers to focus on particular inquiries that require resolution.

Exploration of uranium requires geochemical investigations and gamma-ray spectroscopy. Geochemical investigations might be able to identify uranium anomalies through the analysis of the chemical composition of rocks and sediments. Gamma-ray spectrometry is a non-invasive technique used to map radioactive residues in the Earth's crust. It operates by detecting gamma radiation emitted by radioactive elements such as uranium. By employing these techniques, potential uranium reserves can be identified in advance and investigated further (Langanay, J., Romary, T., Freulon, X., Langlais, V., Petit, G., & Lagneau, V, 2021).

Recently, machine learning (ML) and artificial intelligence (AI) have been incorporated into uranium prospecting. Spectral, geochemical, and geological information are among the mountains of data that machine learning algorithms sift through in search of patterns associated with uranium resources. The utilisation of AI systems' adaptability and learning capabilities enables more accurate predictions while reducing the need for costly exploration. These technologies enable geologists to allocate their attention towards areas that hold greater potential for exploration. By automating data analysis and decision-making procedures, these technologies enhance the efficiency of prospecting endeavours.

Individuals involved in the Uranium Purification Method

The uranium purification procedure is a complex undertaking that requires the participation of numerous stakeholders, all of whom are critical to the operation's compliance, safety, and efficiency. An integrated network of organisations—including mining corporations, processing facilities, and regulatory authorities—supervises the entire purification procedure.

The initial step in the purification process is for mining companies to extract uranium ore from the Earth's crust. To facilitate the transportation of raw materials to processing facilities, these companies allocate financial resources towards exploration, extraction, and transportation technology. To extract uranium from the ore, a sequence of mechanical and chemical processes is implemented (Talan, D., & Huang, Q, 2022). Mining companies often forge agreements with governments to help them manage environmental and safety risks associated with uranium reserve access and utilisation.

Processing facilities are responsible for refining uranium ore. Precipitation, leaching, solvent extraction, and crushing are the processes utilised to acquire yellowcake, which serves as the uranium concentrate. It is imperative that processing facilities conduct thorough assessments of the efficacy and environmental impact of these purification techniques. Ongoing developments in purification techniques, such as in-situ extraction, have led to increased production yields and reduced expenses.

Regulatory bodies such as the International Atomic Energy Agency (IAEA) play a vital role in monitoring uranium processing facilities. To prevent the illicit diversion of uranium and ensure its safe and secure processing, the International Atomic Energy Agency (IAEA) establishes and enforces standards and guidelines. Compliance with international nuclear non-proliferation agreements, safety protocols, and environmental standards is ensured through the partnership between regulatory authorities, processing facilities, and mining companies.

Uranium purification is characterised by a focus on environmental and safety concerns. Environmental and health concerns are associated with the extraction and processing of uranium ore. Consensus among governmental entities, regulatory agencies, and mining corporations guarantees that the extraction and purification of uranium have negligible impacts on nearby populations, water sources, and ecosystems. Since the environmental impact of uranium extraction is already a significant concern, researchers are attempting to develop more sustainable methods of ore purification (Zhang, D., Chen, X., Larson, S. L., Ballard, J. H., Knotek-Smith, H. M., Ding, D., ... & Han, F. X, 2022).

Technological and Methodological Advancements in Purification

Nuclear fuel manufacturing requires multi-stage uranium purification to extract pure uranium for nuclear power and other nuclear energy uses. This section will analyse the complex processes of uranium purification, how technological advances have changed them, and how they affect environmental sustainability and efficiency.

Uranium purification comprises a series of precise steps to treat raw uranium ore for nuclear fuel manufacturing. To enable chemical treatment, the ore is usually reduced to a fine powder. After pulverising the ore, chemical leaching dissolves the uranium and removes contaminants. Yellowcake, or uranium concentrate, is precipitated during solvent extraction, a common method for separating uranium from other elements (Kolhe, N., Damle, E., Pradhan, A., & Zinjarde, S, 2022). These processes remove contaminants and isolate uranium for processing.

Technological breakthroughs in uranium purification make nuclear fuel production more efficient and environmentally friendly. New leaching methods, like in-situ leaching, are significant. In-situ leaching dissolves uranium in its natural habitat by introducing leaching solutions directly into the subsoil, reducing its environmental impact. This process produces less pollution and has a smaller environmental imprint than conventional mining, which is essential for environmental sustainability.

Uranium purification requires solvent extraction, which has advanced technologically. Modern solvent extraction technologies allow for higher yields and lower manufacturing costs. Uranium extraction needs this efficiency boost to stay competitive globally. Recent solvent extraction advances have reduced energy and chemical use, reducing environmental effects.

Improvements to the precipitation step have optimised the uranium purification process. Modern precipitation procedures like, crystallisation and selective precipitation, can better extract uranium from impurities. This approach improves uranium purity by lowering purifying waste. Cost-effective and waste-free, uranium processing is environmentally friendly.

Technological advancements affect uranium purification efficiency. The uranium industry becomes more profitable as extraction yields rise and production costs fall. Increased efficacy helps maintain uranium availability as global nuclear energy demand rises. As more countries explore nuclear energy as an environmentally beneficial alternative to fossil fuels, demand for reliable uranium purification is rising (Surdyk, S., Itani, M., Al-Lobaidy, M., Kahale, L. A., Farha, A., Dewachi, O., ... & Habib, R. R, 2021). Uranium purification advances also affect environmental preservation. Physical disturbance reduction methods like in-situ leaching reduce habitat disruption and ecological damage. Chemicals and energy are used less in solvent extraction and precipitation to reduce industrial emissions. Environmentally sustainable uranium processing is essential for public trust in the nuclear power industry and resource management.

Sustainable uranium purification considers extraction, waste management, and long-term environmental implications. Advances in technology have made uranium processing waste storage and management safer and more environmentally friendly. Improved waste management technologies like encapsulation and geological disposal ensure uranium extraction's long-term viability by lowering radioactive waste risks.

Geological Factors and the Geochemical Environment

Numerous components are in motion during the geological processes that combine uranium with other minerals. Understanding the geochemical context is crucial for comprehending the presence of uranium and other elements in particular geological formations. Several factors influence the amalgamation of uranium with contemporary minerals, including the depositional environment, hydrothermal activity, and the presence of specific mineralising agents.

Significant effects can be observed when uranium is combined with other minerals and the environment in which they precipitate. The deposition of minerals such as uranium, phosphates, and carbonates are prevalent in sedimentary environments, including marine basins and continental margins. Mixed-mineral deposits may result from the co-precipitation of uranium and other elements under a variety of redox conditions in these environments (Surdyk, S., Itani, M., Al-Lobaidy, M., Kahale, L. A., Farha, A., Dewachi, O., ... & Habib, R. R, 2021).

Hydrothermal processes exert a substantial impact on mineral deposition, as they are propelled by the circulation of fluids and heat within the Earth's mantle. Hydrothermal systems are prevalent locations for uranium deposits due to the favourable conditions for elemental fusion, including that of rare earth elements, gold, and copper. To forecast the formation of mixed-mineral deposits, knowledge of the fluid composition, temperature, and pressure during hydrothermal processes is essential.

The potential influence of mineralising agents, such as organic substances or sulphide minerals, on the mixing behaviour of uranium with other contemporary minerals cannot be overlooked. Organic matter-rich sediments might facilitate uranium's combination with other elements and the formation of complexes with uraninite and other minerals. However, it is possible for uranium and sulphide minerals to coexist in environments that are abundant in sulphides.

The Significance of Economic Value Combination

Economic benefits may result from the potential increase in the value of mineral reserves brought about by the integration of uranium with other minerals. Complementary in nature to modern minerals and uranium, this section emphasises the significance of comprehending the mechanisms that result in increased value.

The resource portfolio of the mining industry is diversified through the amalgamation of uranium with additional minerals. Diversification mitigates the risks associated with fluctuations in commodity prices. One should contemplate the increasing demand for rare earth elements (REEs) in the context of renewable energy and technology. The combination of uranium and rare earth elements (REEs) yields a deposit that acquires strategic value (Jyothi, R. K., De Melo, L. G. T. C., Santos, R. M., & Yoon, H. S, 2022).

The technological synergy that results from combining uranium with particular minerals can increase the deposit's economic viability. One potential approach to capitalising on the increasing need for energy storage technology is through the amalgamation of uranium and vanadium, which could yield an ore suitable for the fabrication of advanced batteries.

Co-mining endeavours that target mixed-mineral resources may benefit from enhanced extraction efficiency. Uranium and mineral extraction can remain economically feasible despite challenging geological conditions, owing to the utilisation of shared infrastructure and processing facilities that effectively reduce operational expenses.

To develop strategic mineral supply chains, uranium must be combined with minerals that are critical to various industries. Rare earth elements for electronic devices and phosphates for agriculture are examples of these minerals. Fostering national or regional resilience requires a constant supply of vital minerals and a reduction in reliance on external sources.

The Influence of Geopolitical and Regional Factors

The geographical dispersion of mixed-mineral deposits exhibits significant geopolitical implications as it influences both the dynamics of global mineral supply and regional economic development.

Concentration of Geopolitical Power: Regions endowed with abundant mixed-mineral reserves, specifically those harbouring uranium, attain significant influence in the realm of global affairs. Through active participation in or regulation of critical components of the nuclear fuel cycle, as well as the provision of vital minerals to global markets, countries endowed with such resources may wield influence.

The existence of mixed-mineral deposits has the potential to entice investments in mining and associated industries, thereby stimulating economic growth in the region. When governments utilise these resources intelligently, economic expansion, new employment prospects, and infrastructure enhancement can all ensue (Costa Peluzo, B. M. T., & Kraka, E, 2022).

Although there are evident economic benefits to extracting and processing mixed-mineral resources, there are also possible social and environmental consequences. To safeguard ecosystems, water supplies, and local populations, robust governance and regulatory frameworks are necessary.

Energy Security at a Global Level: The utilisation of uranium in nuclear power plants introduces further intricacy to geopolitical dynamics that are already complex. The utilisation of nuclear fuel for power generation by nations endowed with mixed-mineral deposits, particularly those abundant in uranium, could have a substantial influence on global energy security.

Conclusion

In conclusion, uranium is a substance that transcends the boundaries of technology, science, and the economy. Uranium, with its radioactive characteristics and current medical and nuclear power applications, has emerged as an essential resource. Space exploration and sophisticated nuclear reactors are merely two instances of the element's enduring applications. A comprehensive understanding of the future of global energy requires knowledge of uranium's history, distribution, and market price. Uranium maintains a significant role in the ongoing global energy transition, which is characterised by the pursuit of environmentally sustainable and efficient power sources. An intricate interaction between geopolitical, economic, and geological factors defines the integration of uranium with other contemporary minerals. Mixed-mineral deposits have geostrategic implications that affect regional development, environmental sustainability, and global mineral supply chains, in addition to economic considerations. Sustainable and accountable resource management necessitates a comprehensive approach that considers social, environmental, and economic factors concurrently, given that nations continue to delve further into these resources. The interdependence of uranium and other minerals underscores the complexity of the contemporary mining sector and stresses the need for interdisciplinary approaches to maximise the value of the planet's natural resources.

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Yttrium

Charunivetha

Introduction

The element of Yttrium, represented with the symbol 'Y' on the periodic table, is one of the 17 Rare Earth Metals. Yttrium has an atomic number of 39 and an atomic mass of 88.90585. It has a silvery-white appearance and is moderately reactive. Yttrium derives its name from the town of Ytterby in Sweden, where it was first discovered in 1787 by Karl Arrhenius in its oxide form.[39] Believing it to be a new Tungsten mineral, he passed the discovery to Johan Gadolin who declared it as a new 'earth' in 1794.[40] Friedrich Wöhler achieved the isolation of the metal by reacting Yttrium Chloride with Potassium.[41] Excluding nuclear isomers, the element has 33 isotopes, out of which only Y-89 is a stable, naturally occurring isotope.[42] Yttrium is never found as a free element on the earth's surface. Rather, it is seen in combination with other rare earth elements and some uranium ores.[43] It is also found in mineral rocks like bastnaesite and xenotime and in the form of monazite sands.[44] This report goes into the details of the extraction process, current uses, and potential uses of Yttrium.

Extraction of Yttrium

The utilisation of Yttrium is contingent upon an extraction process as it is never found as a free element. Contrary to the name, rare-earth elements are not necessarily scarce. However, they are usually not found in quantities sufficient to extract cleanly and economically.[45] Therefore, diversifying and innovating new extraction methods will increase the potential for these elements. Although traditional extraction methods have assisted in the use of Yttrium for decades now, growing demand and environmental concerns urge us to look into new methods that will yield the same results more

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[39] "Yttrium - Element Information, Properties and Uses: Periodic Table," Yttrium - Element information, properties and uses | Periodic Table, accessed January 17, 2024, https://www.rsc.org/periodic-table/element/39/yttrium.
[40] Ibid.
[41] Ibid.
[42] "Yttrium," Encyclopædia Britannica, accessed January 17, 2024, https://www.britannica.com/science/yttrium.
[43] Julissa Green, "Uses, Properties & Facts about Rare-Earth Yttrium," Global Supplier of Sputtering Targets and Evaporation Materials | Stanford Advanced Materials, June 22, 2022, https://www.sputtertargets.net/blog/uses-properties-facts-about-rare-earth-yttrium.html.
[44] Carolina Mocelin Pires et al., "Yttrium Extraction from Soils by Electric Field Assisted Mining Applying the Evolutionary Operation Technique," Journal of Cleaner Production 227 (August 1, 2019): 272–79, https://doi.org/10.1016/j.jclepro.2019.04.077.
[45] "China Is Rapidly Monopolizing Rare Earth Elements, Why the World Must Act Now to Stop the Dragon," Latest Asian, Middle-East, EurAsian, Indian News, October 20, 2022, https://www.eurasiantimes.com/the-world-must-come-together-to-stop-chinas-monopoly/.

effectively and efficiently. The following section looks into both the processes and outlines the advantages and disadvantages associated with each method.

Traditional Sources of Extraction

The traditional sources of extraction of Yttrium range from primary sources and secondary sources. As the element is always found in combination with other elements, an elaborate process of separation is required to use the metal. The primary source is extracted using a conventional mining technique, followed by a solvent extraction process in hydrometallurgy.[46] Secondary sources are the waste electric equipments, from which Yttrium is recovered using a solvent extraction process.[47] The conventional mining technique demands high energy consumption, owing to the drilling, excavation, crushing, loading, and transportation stages.[48] This also exerts a negative environmental impact. Similarly, the solvent extraction process also poses the same challenges of high energy costs and environmental concerns.[49] Although the traditional methods cannot be abandoned, it is essential to look into other innovative methods to meet the demand for Yttrium while also cutting costs and reducing environmental damage.

New Alternatives for Extraction

Electromining has emerged as the innovation for the extraction of Yttrium and several other rare earth elements. This process extracts the elements from the soil by transferring the electrons from the soil to an electrode and creating a positively charged element.[50] This ion is then easily extracted from the soil. Electromining is still under testing and development stages. Although there are no proven results, it is a promising alternative to the traditional methods of mining. The costs associated with Electromining are less than those of the traditional extraction methods due to reduced energy consumption.[51] Additionally, the use of weak and biodegradable organic acid ensures that there is no significant harm done to the environment.[52]

Current Uses of Yttrium

The unique chemical and physical properties exhibited by Rare-Earth elements allow for their use in cutting-edge technology across diverse fields. They have found uses in day-to-day technology, defence equipments, medical uses, and several others. Yttrium, as a

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[46] Ibid.
[47] Ibid.
[48] Ibid.
[49] Ibid.
[50] Ibid.
[51] Ibid.
[52] Ibid.

good conductor of heat and electricity, finds its use in several major appliances. Some of these important uses are listed below:

Additive in Alloys

Yttrium’s deoxidizing, desulfurizing, denitrifying, or degassing effects make the element crucial in several alloys to increase their utility.[53] It is most commonly used to increase the strength of aluminium and magnesium alloys. The addition of Yttrium in alloys reduces the mass gain of these alloys.[54] The mass gain is the total mass increase in an alloy as it absorbs atoms or molecules from its environment.[55] A reduced mass gain enhances the surface adherence of these alloys.[56] For example, when Yttrium is added in increasing concentration to Fe-20Cr-4Al (an alloy composed of 20% chromium, 4% Aluminium and Iron as the balance), the oxide surface formed to protect itself increases in strength.[57]

Missile Defence Systems

Yttrium also finds use in several defence systems and in particular, Yttria (Y_2O_3) is used on windows and domes on missiles.[58] Under Navy funding in the 1980s, the US military developed the first full-scale missile domes using transparent Yttria manufactured from Ceramic powders.[59] Out of the 7 yttria windows that were tested under simulated conditions, all 7 survived the wind-tunnel-induced thermal shock.[60] Although MWIR materials (sapphire, ALON, spinel) were more durable, they were not capable of fully transmitting out to the 5-micron wavelength like Yttria was.[61]

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[53] Chin Trento, “Main Applications of Yttrium in Alloys and Phosphors,” Global Supplier of Fabricated Products & Machining Parts, accessed January 17, 2024, https://www.samaterials.com/main-applications-of-yttrium-in-alloys-and-phosphors.html#:~:text=Yttrium%20is%20used%20in%20the,temperature%20oxidation%20resistance%20a%20lot.

[54] Ibid.

[55] Ibid.

[56] Ibid.

[57] Ibid.

[58] Patrick Hogan et al., “Transparent Yttria for IR Windows and Domes - Past and Present,” DTIC, 2004, https://apps.dtic.mil/sti/citations/ADA460289.

[59] Ibid.

[60] Ibid.

[61] Ibid.

Superconductors

Yttrium Barium Copper Oxide (YBCO), discovered in 1987, is commonly used to design and construct superconductors.[62] Before the discovery of YBCO, superconductors did not reach high temperatures.[63] Before the mid-1980s, the highest temperature conceivable by a superconductor was 20K.[64] The discovery of lanthanum copper oxide ceramic, doped with barium, discovered by two IBM researchers, Alex Müller and Georg Bednorz, enabled superconductors to reach a temperature of 35K.[65] However, YBCO can reach a temperature of 93K – a significantly bigger jump from other superconductors.[66] The benefit of high-temperature superconductors is that they can be cooled with the use of liquid nitrogen, rather than liquid helium, used for lower-temperature conductors, which is more expensive than liquid nitrogen.[67] Therefore, YBCO made superconductors cheaper and easier to produce.

Electronics

Besides the above-mentioned, yttrium is also used as a component in several electronic and electrical devices. The YIG (Yttrium Iron Garnet) Technology is used as microwave filters and radars.[68] Yttrium Oxide (Y_2O_3) is utilised in the production of camera lenses to make them heat and shock resistant.[69] Y_2O_3 is also used as a substance in phosphors.[70] Phosphors are substances that emit light when they receive radiation.[71] Depending on the substance used in the phosphor, the nature of the light emitted will vary. Phosphors made with Yttrium are used in LED lights and colour televisions, computer monitors and X-ray-intensified screens.[72]

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[62] Eddie M. W. Leung, David D. Madura, and Richard E. Bailey, "Yttrium Barium Copper Oxide Superconducting to Normal Transition Characterization for a Solenoid Configuration," SpringerLink, January 1, 1990, https://link.springer.com/chapter/10.1007/978-1-4613-0639-9_74.

[63] Neil Withers, "YBCO – Yttrium Barium Copper Oxide," Chemistry World, January 27, 2020, https://www.chemistryworld.com/podcasts/ybco-yttrium-barium-copper-oxide/6148.article.

[64] Ibid.

[65] Ibid.

[66] Ibid.

[67] Muhammad Ikram et al., "High Temperature Superconductors," IntechOpen, March 10, 2021, https://www.intechopen.com/chapters/75641.

[68] "YIG Technology," Microwaves101, accessed January 18, 2024, https://www.microwaves101.com/encyclopedias/yig-technology.

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[70] Chin Trento, "Main Applications of Yttrium in Alloys and Phosphors," Global Supplier of Fabricated Products & Machining Parts, accessed January 17, 2024, https://www.samaterials.com/main-applications-of-yttrium-in-alloys-and-phosphors.html#:~:text=Yttrium%20is%20used%20in%20the,temperature%20oxidation%20resistance%20a%20lot.

[71] Ibid.

[72] Ibid.

Medical Uses

Yttrium finds use in medical equipment and radiotherapy treatments. The YAG (Yttrium Aluminium Garnet) laser technology is popularly used in the medical field. Further, different isotopes of Yttrium are being utilised. Yttrium-90, or Y-90, is used in radiotherapy as it releases high-energy β− particles, which can indirectly cause cell death by increasing the concentration of toxic free radicals present in cells.[73] Additionally, Y-86 is used for PET scans and Y-89 is used for HP-MRI scans.[74]

Potential Uses and Ongoing Research

To utilise the benefits of Yttrium better, research on finding new applications for existing technology on Yttrium and developing new technology altogether is imperative. Although Y-90 is already being used for cancer treatment, a new process of Radioembolization is being explored as a treatment for cancers in the liver.[75] Further, hyperpolarisation is being studied as a new technique for molecular imaging studies.[76] A radioactive form of Yttrium may also be used to locate and bind to cancer cells to treat some forms of cancers.[77] Further, yttrium alloys have the potential to be used as components of spacecraft. But most important of all, research is necessary in the field of the extraction of Yttrium. As of 2022, more than two-thirds of all Rare Earth Elements (REE) are produced in China.[78] This places a risk of supply on REEs and allows China to exercise a monopoly over it. Although the abundance of REEs in China plays a role, the highly advanced and efficient supply chains they operate, remain the main reason for such production.[79] The setting up of such technology would require significant funds and operating costs are also expensive. Thus, research to innovate new processes and technology for the safe and efficient extraction of Yttrium is needed.

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[73] Ben Tickner et al., "The Use of Yttrium in Medical Imaging and Therapy: Historical ...," Research Gate, July 2020, https://www.researchgate.net/publication/343166877_The_use_of_yttrium_in_medical_imaging_and_therapy_historical_background_and_future_perspectives.

[74] Ibid.

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[77] "Yttrium News, Research," News, accessed January 18, 2024, https://www.news-medical.net/?tag=%2FYttrium.

[78] Oct 30, "Rare Earths: Production Share by Country 2022," Statista, October 30, 2023, https://www.statista.com/statistics/270277/mining-of-rare-earths-by-country/.

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Conclusion

Rare Earth Elements have become a vital part of our daily lives, with over 200 applications. Yttrium is one such indispensable element, possessing unique qualities that allow its use in alloy strengthening, missile defence systems, superconductors, electronics, and several other medical applications. Further, ongoing research explores applications like radioembolization for cancer treatment and hyperpolarization for molecular imaging. While traditional extraction methods pose environmental and energy concerns, innovative approaches like Electromining offer promising alternatives with lower energy costs and reduced environmental impact. As the demand for Yttrium increases, for use in several electronic appliances, it is vital to ensure its sustainable, efficient, and safe extraction. Rather than funding new plants for utilising existing extraction techniques, efforts should be focussed on innovating new methods that will not only be less expensive to set up but also be cost-efficient in their operation. To establish Yttrium as a sustainable and integral element in our technological framework, collaborative efforts among scientific communities, industries, and policymakers are crucial. The exceptional characteristics and critical importance of uranium in various sectors, particularly energy production, have garnered considerable interest in it. This study thoroughly examines the multifaceted nature of uranium, encompassing its historical background, source, geological location, market value, current applications, and potential future uses.

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