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Investigating the properties and Usage of Cobalt

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Abstract

This essay is about a study on characteristic and uses of cobalt. The aim of this research is to find out information about characteristic and uses of cobalt. Through library research regarding to its characteristic it is found that Cobalt is a silvery-gray metal that is commonly used as an alloy with Iron and is known for its high tendency to complexes. Cobalt is found in nature in minerals such as Cobaltite CoAsS and Erythrite (Co3(AsO4)2.8H2O), This metal is hard and has little chemical activity. Its reactivity is less than that of iron, and it reacts slowly with dilute acids, releasing Hydrogen Cobalt gives alloys the highest melting point, these alloys are used for armor, saws, and aircraft turbines.Cobalt is used in different areas of life such as industry and medicine. Cobalt was used in ancient times as a bright pigment to color glass vases and as a dye in Egypt. Cobalt, like iron, is essential in our body's metabolism. The Vitallium alloy is used in dentistry and bone surgery, etc. it is also used to make parts for rotary machines and gas turbines. Cobalt – 60, is used for radiography for cancer treatment. In agriculture cobalt ensures the health of plants and animals in the soil and provides the enzymes needed for their growth. It is also used to make permanent magnets. It is used in writing magnetic tapes and computer speakers and electric car motors.

Keywords: *Cobalt, alloys, extraction, chemical, element*

Introduction

In chemistry all of the chemical elements are very important and their understanding are very necessary. These elements have their own special characteristics and uses. Based on their characteristic and uses can be used in different sphere of life. Their characteristic and uses for students, teachers, and experts are very important in order to differentiate them from each other and use them in needed time and facilitate life with.

Based on their importance these elements are taught through chemistry books in schools and universities for students to know the characteristics and uses of them. Cobalt is one of the important element of those elements. Cobalt is a vital metal and is used in various areas of life such as industry and medicine. Neda (2018)

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mentioned that Cobalt is a silvery-gray metal that is commonly used as an alloy and is known for its high tendency to complexes.

So this essay is focused on Cobalt which is an important element in chemistry and it is necessary to know about its characteristic and uses and gain comprehensive information about this element.

Research Methodology

This essay is about characteristic and uses of Cobalt. Library research is used to collect the updated sources and information from different sources such as scientific books websites, research articles in order to obtain important information about Cobalt's characteristic and uses.

The element of cobalt

Cobalt is a metal found in the upper crust of the earth at 4.10^{-3}% (Kani, 2015; Harkup, 2021). Cobalt was first discovered in 1735 by Swedish chemist George Brandt. Because cobalt extraction was very difficult and dangerous, he named it "Kobold," sometimes this process accompanied by poisonous arsenic, its toxicity led German miners to call these two elements cobalt and arsenic as "devil's spirits". Cobalt minerals contain arsenic in their composition and upon heating, poisonous arsenic trioxide (As_2O_3) is separated from it. Those rock that contains these minerals are known as devil spirit among miners .Furthermore, in 1735, the Swedish mineralogist George Brandt was able to isolate a previously unknown metal from these minerals, which he named cobalt and used its green pigment to color glass. (7: 476-477 and 6: 100- 103). Cobalt is a ferromagnetic metal that is found in small quantities on earth, with abundance of approximately 4×10^{-3}.

According to Neda (2018), Cobalt is found in the nature in forms of Co_2S_2 and CoAs, like iron and it is a very essential element in the body's metabolism as it is a component of vitamin B12. Cobalt ores are often found with nickel, iron, and copper., the ore is first converted to Cobalt Oxide (CoO), and then reduce with the help of carbon to obtain metallic Cobalt.

Cobalt contributes to high melting points in alloys, which makes them suitable for high- temperature and maintain their strength even at extreme temperature. These alloys are used for armor, saws and aircraft turbines. In addition, cobalt (60), which is radioactive, emits gamma rays with energies of 1.17 and 1.33 MeV is used in cancer treatment (10: 121).

(Gray, 2009) mentioned that cobalt was used in ancient times as a bright pigment to color glass vases and as a dye in Egypt. Cobalt is found in large quantities with other transition metals. It is usually a by-product of cooper and is used to make permanent magnets. It also has magnetic properties; it is used in magnetic tape recorders, computers, speakers, and electric car motors (Turbo). Cobalt gives allays the highest melting point, maintaining their strength up to the highest nonogram temperatures. These alloys are used for armor, saws, and aircraft turbines (5:66).

Physical and chemical characteristics of Cobalt

According to Kani (2015) the Cobalt atom has 27 protons and 32 neutrons in its nucleus, and 27 electrons in motion around it. It has an electron configuration of [Ar] $3d^7\ 4s^2$,it means that it has four electron energy levels, 2 electrons in the first energy level, eight electrons in the second, fifteen electrons in the third and two electrons in the fourth , and the total number of protons and neutrons is 59 (7:478).

Neda,(2018) Cobalt is a hard and solid metal that exists in two modification states (a and β), where alpha (a) cobalt has a hexagonal crystal structure and beta (β) cobalt has a face center cubic structure. Cobalt exist in two crystalline forms: hexagonal close packed (α-form) below 417°C and faced-centered cubic (β-form) above this temperature up to its melting point. It is stable and resistant at temperatures from 425°C to 1494°C (melting point). Cobalt is a ferromagnetic element with a Curie point of (1121°C). The oxide layer may slightly change the luster but does not generally results in a Yellow color its yellow color is due to the presence of a thin oxide layer (10:111).

According to the theories of Osola (1937) and Tanival(1983), cobalt has an atomic number of 27, an atomic weight of 58.9332, an atomic radius of 135 pm, a boiling point of 5301°F (2927 °C), a melting point of (2723°F 1495°C), and the structure (Ar) $3d^7\ 4s^2$. It has a steel color. It is not affected by humid air, and is resistant to air up to (400 -700°C), because a protective oxide layer forms on its surface. It is slowly affected by acids that are not capable of oxidizing; conversely,

It is easily dissolved in oxidizing acids:

$$Co + 2H^+ \rightarrow Co^{+2} + H_2\uparrow$$

According to Samadi (2009), cobalt metal is hard and has little chemical activity, because the potential of -0.28 volts for the Co^{2+}/Co pair is equal to -0.28 volts, meaning its reactivity is less than that of iron, and Cobalt dissolves slowly in dilute non-oxidizing acids, producing hydrogen gas. However, it dissolves more readily in oxidizing acids like nitric acid and like iron, it has two important oxidation states, 2+ and 3+ and is much more oxidizing than iron 3+ ; because the potential of the Co^{3+}/Co^{2+} pair is equal to 1.84 volts and the potential of the iron pair is only 0.77 volts. Therefore, cobalt is able to oxidize water and release oxygen:

$$Co^{3+}_{(aq)} + e^- \leftrightarrow Co^{2+}_{(aq)}$$

$$\tfrac{1}{2}\ O_2 + 2H_3O^+_{(aq)} + 2e^- \leftrightarrow 3H_2O$$

$$2Co^{3+}_{(aq)} + 3H_2O \rightarrow Co^{2+}_{(aq)} + \tfrac{1}{2}\ O_2 + 2H_3O^+_{(aq)}$$

For this reason, the chemistry of cobalt with a valence of +3 is very limited in aqueous solutions; however, on the contrary , cobalt +3 complexes are very important, stable, and their referential power is much lower than Co3+(12:657).

$$[Co(NH_3)_6]^{3+} + e^- \leftrightarrow [Co(NH_3)_6]^{2+}$$

Its dissolution in nitric acid is accompanied by the formation of nitrogen oxide:

$$3Co + 2HNO_3 + 6H^+ \rightarrow 3Co_2{}^+ + 2NO\uparrow + 4H_2O$$

cobalt in aqueous solutions forms the cobalt Co^{2+} (II) with an octahedral structure of the type $[E\ (H_2O)_6]$. Its important salts are $Co\ Cl_2 \cdot 6H_2O$ (purple-red) color and $Co\ (NO_3)_2 \cdot 6H_2O$ (red), .

Sometimes, both Co^{2+} and Co^3 oxidation states are found in Cobalt complexes. These two ions are derived from the oxides CoO and Co_2O_3, respectively. Cobalt (II)-cobalt (III) oxide, Co_3O_4, is also known. In aqueous solution, cobalt (II) compounds exist as red Co^{2+} ions, anhydrous or undecomposed cobalt (II) compounds are blue. If the separation of cobalt compounds is prevented, the solution gradually turns blue. Cobalt in its compounds is generally divalent or trivalent. In simple compounds, its divalent state is very stable compared to its trivalent state; but the stability of their complex compounds is the opposite. The anhydrous halogenated

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compound CoX_2 is obtained by heating the crystal hydrate compound.

$[Co(H_2O)_4Cl_2]$.

Complex citrus Co^{3+} is mostly obtained from the acidification of citrus Co^{2+}:

$2[Co(NH_3)_6]Cl_2 + 2NH_4Cl + H_2O_2 \rightarrow 2[Co(NH_3)_6]Cl_2 + 2NH_3 + 2H_2O$

$CoCl_2 + 7KNO_2 + 2CH_3\text{-}COOH \rightarrow K_3[Co(NO_2)_6]\downarrow + NO + H_2O + 2CH_3\text{-}COOK$

Co(III) exhibits a coordination number of 6 and forming octahedral complexes with ligands such as SO_4^{2-}, NO_3^-, OH^-,NO_2^-, Cl^-, NO, H_2O, NH_3, etc. participate in it, and it produces various types of complex covalent bonds (11: 145) and (13: 304, 306, and 309).

At high temperatures, cobalt monoxide (CoO) can be obtained in its alpha or beta form. The combined oxides of cobalt are oxidized by hydrogen. For instance, cobalt (II), cobalt (III) are oxidized by hydrogen to form cobalt.

$Co_3O_4 + 4H_2 \rightarrow 3Co + 4H_2O$

Cobalt (III) oxide Co_2O_3 is obtained in the presence of heat and by the reddening cobalt (II). For example, Co $(OH)_2$ forms the aforementioned oxide upon heating (7:481)

$4Co(OH)_2 + O_2 \rightarrow 2Co_2O_3 + 4H_2O$

According to Duffy's theory (1991), cobalt (III) forms numerous complexes, all of which are octahedral. These complexes are often much more stable in solution than the hexa cobalt (II) ion. If solutions of ammonia and ammonium chloride are added to a solution of cobalt (II) chloride, the presence of air is sufficient for its oxidation, and the main product is the pentaamine cobalt (III) ion and the following equilibrium can be considered for this interaction (4: 359).

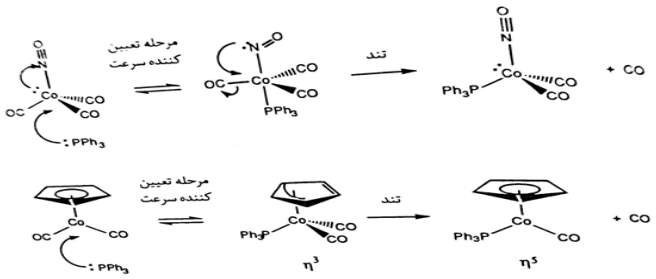
$4[Co]^{2+} + 2ONH_3 + 4Cl^- + 4H_2O_2 \rightarrow 4[Co(NH_3)_5Cl]^{2+} + 4OH$

According to Mingus theory (2001), ligand substitution reactions in transition metal complexes, especially in d^8 square planar complexes such as $[PtCl_4]^{2-}$, $[PdCl_4]^2$ or $[Ni(CN)_4]^{2-}$, occur in two general mechanisms.

1 – direct method (Associative –A) : In this mechanism the entering ligand directly attacks the central metal atom.

2- Indirect method (interchange Associative –Ia): in this mechanism first a molecule from the solvent like methanol or dimethyleformamide (DMF) coordinates to the metal and then the new ligand replace the old one. Activation volumes for these reactions are typically in the range of -10 to -5cm^3/mol, which supports an associative or partially associative pathway.

Ligand exchange reactions of 18-electron organometallic complexes, whose ligands can act as (n) or (2-n) electron donors (such as C_5H_5 or NO ligands) also have a collective mechanism. In these reactions, the starting complex, the final product, and the transition state complex all follow the Effective Atomic Number (EAN) rule.



Increasing the interaction between the metal and the ligand increases the cleavage energy. This effect is more distinct with changes in the metal atom. For instance, the cleavage energy increases in the order: 3d < 4d < 5d; because with the increase in the principal quantum number, the range of (d) orbitals increases, as these orbitals are able to effectively interfere with the ligand orbitals; therefore, in the expression $BS^2\sigma/\Delta E$, the values of Sσ and Sπ increase. The following order is based on the observed Δvalues.

$Fe^{3+} < Co^{3+} < Rh^{3+} < Ir^{3+} < Pt^{4+}$

Increasing the covalent nature of the metal-ligand bond increases the value of Δ in the transition element series.(8:21 &97).

$Mn^{2+} < V^{2+} < Co^{2+} < Fe^{2+} < Ni^{2+}$

Cobalt is also included in the composition of some organic compounds, one of its organic compound is $Co(C_5H_5)_2$, known as Cobaltocene, and has a similar structure to $Fe(C_5H_5)_2$, Ferrocene, with the difference that Cobaltocene contains Co^{2+} ions and Ferrocene contains Fe^{2+} ions. The oxidation activity of Cobaltocene is much higher than Ferrocene.

Cobalt, Rhodium and Iridium with other metals forms interphase cobalt and solid solutions. The physicochemical and mechanical properties of the alloys obtained are determined by each of the specific metals (Ir, Rh, Co) included in the structure of these alloys. For example, Vitallium, alloy (alloy of 65% cobalt, 28% chromium, 3% nickel, and 4% molybdenum) is used in dentistry, bone surgery. It is also used to make parts of rocket engines and gas turbines.

Cobalt (II) Citrus solutions of divalent cobalt salts has red color because these solutions contain the red complex ion $[Co(H_2O)_6]^{+2}$.

The anhydrous divalent cobalt salts have a pure blue color. The removal of water from $CoCl_2 \cdot 6H_2O$ is very easy, and even when heated to 35°C, it acquires a blue color.

When the compound $Co(NO_3)_2.6H_2O$ is heated with aluminum sulfide or Al_2O_3, a blue spinel $MgAl_2O_4$ is formed, which is used to identify aluminum. Similar to the above reaction, roasting $Co(NO_3)_2 \cdot 6H_2O$ with Zn in the presence of oxygen also produces a green spinel, $ZnCo_2O_4$ (Rinmanns green), which is useful for identifying zinc.

Adding ammonium sulfide ($(NH_4)_2S$ to solutions of cobalt (II) salts in the absence of air, form a black precipitate of CoS, which re-dissolved in dilute hydrochloric acid (HCl).

$CoS + 2HCl \rightarrow CoCl_2 + H_2S$

Cobalt in its compounds has an oxidation number of +2, Co^2 salts such as:

$Co(NO_3)_2.6H_2O$,

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$CoCl_2$ $6H_2O$, $CoSO_4$, $7H_2O$, $(NH_4)_2$ $(Co(SCN)_4)$

For example, the Co^{+3} complex is $[Co(NH_3)_6]$ Cl_3.

Cobalt Extraction Method

According toTanival theory (2003), the production of cobalt and nickel requires relatively complex operations because the amount of these elements are less and are found mixed with other metals. Their isolation from other metals goes through several stages until they are finally obtained in the form of their respective oxides and are then refined by carbon in special furnaces (13:304).

Kani (2015) mentioned that cobalt is generally obtained from nickel ore and reacts with acids such as sulfuric acid H_2SO_4 or ammonia NH_3 and release hydrogen(H_2). It is also obtained by pyro metallurgical methods, used nickel, which has similar properties to cobalt. It reacts with chloride ions (Cl^-) and forms cobalt chloride and in reaction with perchlorate ions($ClO4^-$) forms $[Co(ClO_4)_2]$ complexe.

Cobalt minerals include, carolite $CuCo_2S_4$), linnaeite (Co_3S_4), cobaltite (CoAsS), sephaero cobaltite ($CoCO_3$), cobalt arsenide ($CoAs_2$), and skutterudite (Co,Ni) As_3, etc. 30 minerals containing cobalt are known and these minerals also contain iron, manganese and cooper.

Cobalt mines are found in Congo, Canada, America, France, Zambia, Kazakhstan and Russia. (7: 476).

According to Baum (1977), most of the world's cobalt production comes from copper (Cu) and iron (Fe) ores. The most important cobalt ores are: ($CoAs_2$) and cobalt (CoAsS). For industrial or technical extraction of cobalt, copper and iron ores, along with cobalt, nickel or other materials containing silicic acid, are roasted together, where the most of the iron is converted to silicate and separated as slag, which is continuously removed from the furnace. The oxides of copper, cobalt, and nickel are dissolved in hydrochloric (HCl) and gradually precipitated with chlorinated lime to obtain cobalt (III) oxide (Co_2O_3), which is converted to metallic cobalt by carbon or charcoal (2:239)

$$Co_2O_3 + 3C \rightarrow 2Co + 3CO$$

According to Neda theory (2018), cobalt is used in the production of various alloys. Cobalt (Co) and manganese (Mn) are included in the catalyst compositions, which is added to oil paints to make them dry faster. Vitallium alloy (65% cobalt, 28% chromium, 3% nickel, and 4% molybdenum) is used in dentistry and bone surgery, etc. it is also used to make parts for rotary machines and gas turbines. Coated carbides (also called hard metals) are used to make magnets and magnetic recording devices (such as cassettes). cobalt (60), which is radioactive, emits gamma rays with energies of 1.17 and 1.33 MeV is used in cancer treatment (10: 113-114).

Essential Alloys and super-alloys of Cobalt

As research of Demirkan in (22 August 2019) found that platinum-cobalt (pt-co)alloy nanoparticles were synthesized using a microwave assisted method and subsequently combined with reduced grapheme oxide (rGO) to fabricate an electrochemical sensor. This sensor demonstrated high sensitivity for the simultaneous detection of ascorbic acid , dopamine and uric acid .The developed sensor exhibited excellent electrochemical activity ,a broad linear response range ,high sensitivity and acceptable detection limits for reach of mentioned biomolecules.

Alloy Composition Percentages

In this study, Various molar ratios of the Pt -Co alloy were investigated .Specifically, Pt: Co ratios of 3:1,1:1 and 1:3 were synthesized and evaluated. The results revealed that the 1:1 molar ratio delivered the most effective electrochemical performance, which was attributed to the optimal balance between the catalytic activity of platinum and structural stability offered by cobalt (Nature Scientific Reports).

Cobalt-based superalloys strengthen through mechanisms different from those of nickel-based superalloys. They have good thermal properties up to about 1000 °C and contain chromium, resist corrosion and oxidation, and are weldable and resistance to thermal fatigue.(if failure occurs under thermal stress, the condition is called thermal shock). However, if failure occurs after repeated application of thermal stresses (this is called thermal fatigue), their thermal fatigue resistance is generally lower than nickel-based alloys. On the other hand, the possibility of melting and casting this alloy in air with an argon atmosphere is another advantage over other super-alloys that require a vacuum.

Among the cobalt-based alloys, Haynes 25(L-605) has been the most widely used alloy. It is used in the manufacture of hot worked parts such as gas turbines nuclear reactor components, surgical implants, etc. cobalt – based group alloys, which include chromium, tungsten, and carbon, are known as stellite alloys, which are highly resistant to wear (the gradual destruction of metals by environmental factors like oxygen and moisture).this group is usually used in cases where wear resistance at high temperature is required. In fact, the hardness of these materials maintained at high temperature and they are well used in cases where lubrication cannot be done during operation.

According to U.S. Geological survey (USGS.Gov ,2011). the use of cobalt in medicine may seem a bit strange, that this toxic and dangerous metal, extracted from mines and causing the death of many mine workers. Co-60 is used in medicine for radiography due to its high energy gamma emission. The first specialized device for this purpose was produced in Canada, known as the “cobalt bomb” and it meets the need for five years of cancer treatment. Cobalt is an essential component of vitamins B12. Vitamin B12 is a vitamin that is essential for the treatment of anemia. Cobalt containing compounds like hydroxocobalamine are used to treat cyanide poisoning.

cobalt used as an element in rechargeable batteries, especially lithium batteries. Today, examples of these batteries can be found in electronic devices such as cell phones, laptops, and electric cars (PUBS.USGS.GOV).

Black cobalt oxide, Co_3O_4, can be used as a selective absorber in solar collector due to its high thermal stability and black color. Cobalt (II) oxide is used in thermistors. A thermistor is a type of variable resistor whose value changes with temperature.

Cobalt is used as the main material for the covering of magnetic recording types such as cassette tapes and video-tapes without cobalt, sound recording would not be possible. Cobalt is also used in paint and glass industry. Blue and green cobalt are used as coatings for porcelain glazes and ceramics and as pigments for glass. This element is the drying agent in paints, inks, and glosses.

The use of cobalt in agriculture (soil) ensures the health of plants and animals in the soil and provides the enzymes needed for their growth. Cobalt is also used as a catalyst based on cobalt and molybdenum, which play an important role in the removal of

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sulfur; therefore, they can be used to remove sulfur from oil and gas and purify them for refining. These catalysts play an important role in processes involving carbon monoxide, including the Fischer-Tropsch process to convert carbon monoxide and hydrogen into liquid hydrocarbons.

According to Smantha& Halder (2024) cobalt based nanomaterial are a low cost alternative to precious metals like platinum for hydrogen production. Their highly nano- structure and ability to combine with oxides, phosphides sulfide and carbides improve catalytic performance, they also offer high thermal stability and recyclability making them strong candidates for further clean energy technologies (ACS.ONLINE LIBRARY.WILEY.COM).

According to Andery . (February 2022) One of the most critical areas of application of cobalt nanoparticles is their use as a catalyst. For example, cobalt nanosystems catalyze the hydrolysis of natrium borane (1), which is a reaction to produce hydrogen, one of the environmentally friendly fuel and efficient energy carriers (RESEARCHGATE +2).

$NaBH_4 + 2H_2O \rightarrow NaBO_2 + 4H_2$

According to Picaszo (2023) cobalt is a critical metal primary sourced from the Democratic Republic of the Congo, Russian and China, often as by a by-product of nickel and copper mining. Due to increasing demand in renewable energy and battery industries, recycling from lithium – ion batteries has become vital. Given the geographical risks associated with major reserves, sustainable extraction, recycling, and alternative sourcing are essential for long- term supply security (RESEARCH GATE).

A study conducted by Qaeda borborzzaidi , Khesravi & Abasi (2025) presented at the first international and second international Lithium Battery conference demonstrated that the addition of cobalt to titanium- based compounds in lithium – ion battery anodes can significantly enhance battery performance capacity.

For cobalt alloying, the elements chromium, molybdenum, iron, tungsten, manganese, titanium, aluminum, niobium, vanadium, and beryllium are the most common elements added to cobalt, each of which gives the alloy its own unique properties. Chromium, molybdenum, and tungsten increase the alloy's strength and resistance to high temperatures and wear. Nickel increases the toughness of the alloy (toughness is the ability of a material to absorb energy and undergo plastic deformation before failure occurs, or in other words, the amount of energy that a material can absorb before breaking). Carbon is usually formed as carbide and increases the wear resistance and hardness of the alloy.

Elements like iron, aluminum, titanium, and vanadium are added to the alloy to increase the repulsive force (repulsive force is the force added to neutralize the magnetic properties, including reducing residual magnetism in cobalt –based alloys). In general, cobalt alloys can be divided into three categories: Wear-Resistant Alloys, Corrosion-Resistant Alloys and Heat-Resistant Alloys.

Heat- resistant Alloys

Cobalt has a Face-Centered Cubic (FCC) crystal structure at high temperatures and shows good resistance to creep and changes in strength with temperature. The Curie temperature of cobalt is very high (about 1,115°C), which shows its high resistance to vibration, pressure, and heat. Although cobalt alloys have lower thermal conductivity than nickel alloys, their resistance to oxidation and sulfidation makes them suitable for enviroments.

Among the uses of cobalt-based alloys is their use in turbine blades, which are constantly exposed to corrosion caused by the combustion of petroleum or natural gas. These alloys are also suitable candidates for use in jet aircraft engines to their high heat resistance.

Corrosion Resistant Alloys

Corrosion in cobalt-based alloys can be examined from three main aspects: sliding corrosion, abrasion corrosion, and chemical corrosion. The appropriate alloy must be selected based on the type of corrosion in place:

1- Sliding Corrosion: This occurs when two surfaces slide roll over each other repeatedly and hard. If both of these surfaces are metal, the possibility of slipping and corrosion will be higher. Cobalt alloys have high resistant to corrosion and slipping due to the presence of elements like carbon

2- Corrosion and Wear: when two surfaces slide together, particles will be peeled off their surfaces due to corrosion, as a result, over the time, the surfaces will find a bottom, and during service, more particles will be peeled off their surfaces because of corrosion. These bottom surfaces and the wear of the peeled particles create a type of corrosion which is known as wear corrosion. Cobalt alloys are considered hard alloys due to the elements of carbon, chromium, and tungsten. Including the alloy called Vitallium which is an alloy of cobalt, chromium, and molybdenum, and is used in biomedical applications like knee prostheses due to its high wear and corrosion resistance.

3- Chemical Corrosion: this type of corrosion occurs when the alloy is exposed to a chemically corrosive environment. For example, environments where the transfer of acid, alkaline solutions with corrosive salts occurs. Cobalt alloys have high resistance to corrosive environment, especially sulfide environments, and most of them are used in pumps, reactors, agitators, and solution transfer pipes.

Wear Resistant Alloys

At the beginning, we mentioned that the elements chromium, molybdenum, and tungsten increase the corrosion resistance of cobalt alloys. It is interesting to note that cobalt also increases the strength of these metals in the alloyed state due to its special crystal structure. Adding a combination of these elements creates a strong alloy known as Stellite. Stellites are alloys composed of cobalt, carbon, chromium, molybdenum, and tungsten that have high wear resistance. These alloys require little lubrication and have a low coefficient of friction. These alloys also exhibit high resistance to oxidation and wear, making them excellent candidates for anti – wear applications. (https://iran.mavad.com) and (Vista.ir/m/a/ag9m1) Vista Magazine.

Findings

This article is a study about characteristic and uses of a chemical elements of cobalt. Through library research it was found that Cobalt is a metal found in the earth's upper crust. Cobalt is found in the nature in forms of Cobaltite CoAsS , Cobalt Arsenide $CoAs_2$ and Carrollite $Cu(Co,Ni)_2S_4$ like iron. it is a silvery-gray,hard and lustrous metal commonly used as an alloy with iron and exhibits a strong tendency to form complexes. Its reactivity is less than that of iron, and it slowly dissolves in dilute acids, producing hydrogen gas. The extraction of cobalt and nickel requires complex processes

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because these elements are less and are found mixed with other metals. Cobalt is used in the production of various alloys.

Cobalt has different applications. Cobalt was used in ancient times as a bright pigment to color glass vases and as a dye in Egypt. Cobalt, like iron, is important element in our body's metabolism because it is one of the essential components of vitamin B12 (Cobalamine) which is necessary for red blood cells. Cobalt contain alloys and super alloys which exhibit great thermal stability. These alloys are used for armor, saws, and aircraft turbines. In agriculture cobalt ensures the health of plants and animals in the soil and provides the enzymes needed for their growth.Vitallium alloy (65% cobalt, 28% chromium, 3% nickel, and 4% molybdenum) is used in dental implants and bone surgery and etc. It is also used to make parts for rotary machines and gas turbines.

Cobalt – 60,is a radioactive which known as a cobalt bomb, emits gamma rays and is used for cancer radiotherapy and radiography.

Cobalt has magnetic characteristic that used in magnetic tape writing, computer speakers, and electric car motors (Turbo). cobalt like iron has two important oxidation states, +2 and +3; but cobalt +3 is much more oxidizing than iron +3. Cobalt is found in nature in minerals such as Cobaltite CoAsS and Erythrite ($Co_3(AsO_4)_2.8H_2O$),. To obtain cobalt, the ore must be converted to CoO oxide and then refined with the help of carbon.

Discussion

Cobalt is an important element among the chemical elements. Cobalt is a metal found in the earth's upper crust at 0,004% as it is emphasized by (Kani, 2015; Kathryn, 2021). Cobalt is found in nature in minerals such as Cobaltite CoAsS and Erythrite ($Co_3(AsO_4)_2.8H_2O$ and is a silvery-gray metal that is commonly used as an alloy and is known for its high tendency to complexes (Hossein, 2018).

According to Aref (2003) The production of cobalt and nickel requires relatively complex processes because the amount of these elements are less and are found mixed with other metals.

Ali Afzal (2009) mentioned that this metal is hard and less reactive than iron and it slowly dissolves in dilute acids like hydrochloric acid forming cobalt salts and releasing hydrogen gas.in addition Cobalt gives alloys the highest melting point, maintaining their strength up to the high and extreme temperatures. These alloys are used for armor, saws, and aircraft turbines as it is mentioned by (Gray, 2009).

Moreover, cobalt is generally obtained from nickel ore and also it is obtained by pyro metallurgical methods as it is revealed by, Kani (2015).

Related to cobalt's uses it is was used in ancient times as a bright pigment to color glass vases and as a dye in Egypt. Cobalt is very important element in the body's metabolism because it is one of the essential components of vitamin B12 (Cobalamine) which is necessary for red blood cells. Cobalt also plays a key role in the extraction of vitamins B12. Cobalt ores are often found with nickel, iron, and copper. Cobalt in agriculture ensures the health of plants and animals in the soil and provides the enzymes needed for their growth. Vitallium alloy (65% cobalt, 28% chromium, 3% nickel, and 4% molybdenum) is used in dental implants,bone surgery, etc. it is also used to make parts for rotary machines and gas turbines as it is mentioned by Hossein (2018). The elements chromium, molybdenum, iron, tungsten, manganese, titanium, aluminum, niobium, vanadium, and beryllium are the most common elements added to cobalt, each of which gives the alloy its own unique properties. Chromium, molybdenum, and tungsten increase the alloy's strength and resistance to high temperatures and wear.

Conclusion

Cobalt, like iron, is essential to human metabolism because it is a component of vitamin B12. Cobalt has a lower reducing power than iron, it slowly dissolve in dilute acids, releasing hydrogen gas and forming cobalt (II) salts. Cobalt is found in nature in minerals such as Cobaltite CoAsS and Erythrite ($Co_3 (AsO_4)_2.8H_2O$ ₂, and its ore is typically found with nickel, iron, and copper. To obtain cobalt, the ore is first converted to cobalt (II) oxide (CoO) and then refined with the help of carbon. Cobalt metal is characterized by its hardness and relatively low chemical activity because the potential of Co^{2+}/Co pair is -0.28 volts and like iron, cobalt has two oxidation states, +2 and +3; however, Co^{3+} is a stronger oxidizing agent than Fe^{3+}. Therefore, cobalt does not oxidize water under standard conditions.

Cobalt is present in the composition of some organic compounds such as Cobaltocene [Co ($C_5H_5)_2$] and has a similar structure to Ferrocene [Fe ($C_5H_5)_2$]. Cobalt alloys are considered hard alloys because they contain the elements as carbon, chromium, tungsten and when added to steel, it increases the strength and hardness of the steel. Finally, I recommend that the esteemed Ministry of Public Health of the Islamic Emirate to establish a radiography center for cancer treatment to prevent our compatriots from wandering to foreign countries.

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