S-block elements: pharmacological properties and potential medical applications of alkali and alkaline earth metals

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Abstract

Background:

The periodic table contains the s-block elements in groups 1 and 2. In the periodic table, they reside in the first two columns. S-block consists of 14 elements that include hydrogen (H), lithium (Li), helium (He), sodium (Na), beryllium (Be), potassium (K), magnesium (Mg), rubidium (Rb), calcium (Ca), cesium (Cs), strontium (Sr), francium (Fr), barium (Ba), and radium (Ra) as illustrated in **Table 1**. These elements are called s-block elements because their valence electrons are in the s-orbital. Alkali and alkaline earth metals are widely employed in synthetic and chemical technology. Over the past ten years, a growing number of target molecules have been identified in chemistry due to the increased attention it has received because of its diverse uses. **Methodology:** Articles were searched using the following search engine: PubMed, Google Scholar, Worldwide Science and Research Gate, etc.

Result: S-block components are vital to life as they are essential for metabolism, protein synthesis, and brain development. The diverse uses and effects of alkali metals and alkaline earth metals in medicine and research have been discussed in review.

Conclusion: Lastly, the review covers the historical background and pharmacological potential of s-block elements and their properties, uses, and potential medical applications, such as mood stabilization, neuroprotection, anti-inflammatory activity, diagnostic imaging, vasodilatory activity, and cardioprotective activity.

1. Introduction

The ancient Greek philosophy of nature first appeared where the idea of its components first emerged (1). Empedocles (5th century B.C.) asserted that all matter was composed of the four basic "elements" of fire, air, water, and earth, which were brought together and divided by the two "active forces" of love and conflict (2, 3). Only 13 elements in the contemporary sense of the word were known up to the 17th century, and by known, we mean that they had been employed in a relatively pure condition. An avalanche of elemental discoveries began in the second half of the 18th century and has continued to this day. There are now 118 elements (4)

The periodic table elements are arranged so that elements with comparable electron configurations are grouped together (7). Blocks can be created from elements in comparable groups or columns

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according to the electron orbital that the valence electrons of those elements occupy (8). The four blocks represent Four distinct electron orbitals; s, d, p, and f (9).

Deep roots may be found in the 18th and 19th centuries when investigating s-block constituents (10). The narrative starts in the late 18th century with the publication of Antoine Lavoisier's seminal study on chemical elements and their compounds (11, 12) . Group 1 of the periodic table is occupied by hydrogen (included in this group due to its electronic configuration) and alkali metals, which contain lithium, helium, sodium, potassium, rubidium, cesium, and francium. These are soft, glossy, low melting, highly reactive metals (apart from hydrogen), that tarnish when exposed to air (13). These elements display remarkable reactivity, especially with water, and their qualities became increasingly evident via the efforts of pioneers such as Sir Humphry Davy, who separated numerous alkali metals such as potassium, sodium, and lithium using electrolysis (14).

The alkaline earth metals of Group 2, which include beryllium, magnesium, calcium, strontium, barium, and radium, also attracted interest as the 19th century went on. Chemists such as Antoine Bussy and Sir Humphry Davy were instrumental in identifying and defining these components (15). These elements' compounds dissolve in water to generate basic (pH greater than 7) or alkaline solutions, thus the term "alkaline (16). These substances are effective electrical conductors. When first cut, they have a grey-white brilliance but tarnish quickly in the air (17).

Synthetic and technical chemistry make significant use of alkali and alkaline earth metals (18, 19). Because of its many uses, structural chemistry has attracted a lot of attention, and throughout the past ten years, a growing number of target molecules have been identified (20, 21). While alkaline earth metals produce alkaline oxides and hydroxides in the earth's crust, alkali metals are not found in nature in their free state (22).

2. Survey Methodology

A comprehensive search for relevant literature was conducted using multiple databases, including PubMed, Google Scholar, Worldwide Science, and ResearchGate. The search strategy involved keywords and combinations related to alkali and alkaline earth metals' pharmacological properties and medical applications. The search terms included s-block elements, alkali metals, alkaline earth metals, pharmacological properties, medical applications, hydrogen, lithium, sodium, potassium, rubidium, cesium, francium, beryllium, magnesium, calcium, strontium, barium, radium. Articles that addressed the pharmacological characteristics of alkali and alkaline earth metals and detailed

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their possible therapeutic uses were considered for inclusion in the review. To ensure the relevance and accessibility of the information, only articles published in English were considered.

Additionally, the availability of full-text versions of the articles was a prerequisite for inclusion in the review. On the other hand, articles were excluded from the review if they were not available in full text. Publications in languages other than English were also excluded to maintain consistency in language comprehension and analysis. Furthermore, articles that did not focus on the target elements' pharmacological properties or medical applications were deemed irrelevant and thus excluded from the review. Relevant data from the included studies were extracted and reviewed, encompassing information on the historical background, pharmacological properties, medical applications, and potential therapeutic benefits of the s-block elements. The review explored the uses of these elements in various areas, such as mood stabilization, neuroprotection, anti-inflammatory activity, diagnostic imaging, vasodilatory activity, and cardioprotective activity, among others. The search resulted in numerous publications detailing the various applications and properties of alkali and alkaline earth metals.

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Key findings from these studies include the role of hydrogen in reducing oxidative stress and inflammation and the effectiveness of lithium in mood stabilization and neuroprotection. Sodium and potassium were found to have crucial functions in maintaining electrolyte balance, muscle contraction, and cardiovascular health. Rubidium and cesium were also highlighted for their diagnostic and therapeutic uses in medical imaging and cancer treatment. Furthermore, helium's anti-inflammatory, antioxidant, and neuroprotective properties were also identified. The literature review underscores the significant pharmacological potential and diverse medical applications of s-block elements. These findings advocate for the ongoing research and development of therapies that utilize alkali and alkaline earth metals to treat various health conditions.

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3. Pharmacological potential of S-block elements

3.1. Hydrogen

The English chemist Henry Cavendish discovered hydrogen in 1766 (23). Hydrogen is composed of diatomic molecules of H_2. At 75% by weight, or 88% of all atoms in the cosmos, it is the most plentiful element; hydrogen and helium make up 99% of the universe's "normal" matter (24). It is acknowledged that molecules such as molecular hydrogen are inert and nonfunctional in human bodies. Strong oxidants like hydroxyl radicals in cells react with H_2, which has been shown to have

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potential uses in both therapeutic and preventative measures (25). Given how quickly H_2 diffuses into tissues and cells, it offers a variety of benefits with wide-ranging impacts (26). H_2 promotes energy metabolism and has anti-inflammatory and anti-apoptotic properties (27). Hydrogen research has advanced quickly in recent years due to the growing evidence that molecular hydrogen is a particularly effective therapy for numerous illness models, including ischemia-reperfusion damage (28). It has been demonstrated that hydrogen is beneficial whether consumed as a gas and administered orally, intravenously, or topically as a liquid treatment (29, 30).

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3.1.1. Antioxidant activity

Given how quickly H_2 diffuses into tissues and cells, it offers a variety of benefits with broad-ranging effects (31). Reactive oxygen species (ROS) are very reactive oxygen-containing chemical species that can harm tissues and cells (32). Diatomic hydrogen has been suggested as a new type of antioxidant that preferentially lowers harmful reactive oxygen species levels (33). H_2 (orally eaten or breathed, usually as 0.8 mM H_2-saturated water) has been shown in several recent studies to have positive effects in various animal models of neurological, inflammatory, and ischemia-reperfusion damage (25). Oral H_2 saturated water therapy has been shown to enhance glucose and lipid metabolism in individuals with diabetes mellitus or impaired glucose tolerance in the clinic; encouraging outcomes have also been demonstrated in reducing inflammation in patients receiving hemodialysis and treating metabolic syndrome (28). According to research, H_2 may have antiapoptotic, anti-inflammatory, and antiallergenic benefits in addition to its specific antioxidant capabilities (34).

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3.1.2. Anti-inflammatory activity

It has been demonstrated that molecular hydrogen lowers pro-inflammatory cytokine levels, signaling molecules contributing to the inflammatory response (35). Hydrogen could reduce inflammation by adjusting the expression of these molecules. Specific inflammatory signaling pathways, such as the nuclear factor-kappa B (NF-κB) pathway, may be inhibited by hydrogen (36). One transcription factor for controlling inflammatory and immunological responses is NF-κB (37). According to studies, hydrogen-rich water at 0.5–1.0 mM concentrations, or 1-4% hydrogen gas may have anti-inflammatory properties and even prevent NF-kB activation (38).

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3.1.3. Neuroprotective activity

Treatment with hydrogen reduces the size of infarcts, enhances cognitive performance following traumatic brain damage, protects against the loss of dopaminergic neurons in Parkinson's disease, has antioxidant benefits in Alzheimer's disease, and lessens oxidative stress in newborn hypoxic-ischemic encephalopathy (39, 40).

3.2. Lithium

The element's name comes from the Greek word "lithos", which means stone (41). The soft, silvery metal lithium is very low density, interacts violently with water, and tarnishes quickly in air (42). Although it was only produced in small amounts, lithium was one of the three elements created during the Big Bang (43). Johann August Arfvedson discovered lithium in the mineral petalite (LiAl $(Si_2O_5)_2$) in 1817 in Stockholm, Sweden (44-46). William Thomas Brande and Sir Humphrey Davy were the first to isolate it using lithium oxide (Li_2O) electrolysis (46, 47). They observed that the new element generated an alkali solution when dissolved in water and had a red flame color similar to strontium (6). By electrolyzing molten lithium chloride, Robert Bunsen and Augustus Matthiessen generated substantial amounts of the metal by 1855 (48). Lithium comes from the Greek word "lithos," which means stone (49).

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3.2.1. Mood Stabilization activity

Since its introduction in psychiatry at the end of the 1940s, the monovalent cation lithium has been the first-choice medication for treating people with bipolar disorder (BD) (50). It lowers the risk of suicide and is helpful in the treatment of moderate-to-severe acute mania as well as a preventative measure against repeated manic and depressive episodes. Additionally, it can enhance the efficacy of antidepressants when used to treat major depressive disorder (51). Bipolar disorder and certain forms of depression are treated with lithium salts (such as lithium carbonate and Li_2CO_3), which are also used to enhance the effects of other antidepressants (52). By increasing serotonin and norepinephrine activity, Eskalith (lithium carbonate) works as an antidepressant and helps to stabilize mood (53). By blocking inositol monophosphates, it lowers inositol levels and modifies the release of neurotransmitters (54). Lithium also promotes neurogenesis by raising brain-derived neurotrophic factor (BDNF) (55). Moreover, it suppresses glycogen synthase kinase-3 (GSK-3), which modifies signaling pathways linked to mood (56). Finally, lithium further modifies excitability and lessens mood swings by stabilizing neuronal cell membranes (57).

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3.2.2. Suicidal prevention activity

Most bipolar disorder patients should be offered lithium as their first treatment, especially if they exhibit suicidal thoughts or behaviors, and they should be given enough information regarding the drug's possible long-term advantages as well as adverse effects (58). Many people can take lithium without the need for antipsychotics or antidepressants, which could have serious long- term adverse effects or worsen the illness, respectively (59). Treatment with Li substantially lowers "impulsive-aggressive" behavior, a susceptibility factor linked to bipolar disorder and suicide, by targeting the serotoninergic system specifically (60).

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3.2.3. Neuroprotective activity

Lithium modulates neurotransmitters, calcium, potassium, and other neurotrophic and neuroprotective proteins, supporting protective signaling pathways in neuronal cells. According to clinical reports, lithium might be a helpful supplement to treat Parkinsonism and help regulate the "on-off" phenomena (61). Lithium at doses of 1.25, 2.5, 5, and 7.5 mM by downregulating tau proteins protects neurons from the harmful effects of amyloid beta (Aβ) and apoptosis (62, 63). Lithium prevents apoptosis, which contributes to its neuroprotective properties (62, 64-66). The neuroprotective effects of lithium are mediated through the inhibition of intrinsic and extrinsic apoptotic mechanisms (67, 68).

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3.2.4. Anti-inflammatory activity

Lithium can reduce inflammation by preventing the synthesis of two important inflammatory cytokines, interleukin (IL)-1 beta and tumor necrosis factor (TNF)-alpha. These mechanisms reinforce the way that lithium prevents neurodegeneration during neuroinflammatory events (69-71).

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3.3. Helium

August 18, 1868, saw the discovery of helium in the form of a brilliant yellow line (72). After hydrogen, helium is the second-most plentiful and lightest gas in the universe. Numerous uses for helium exist in biomedicine (73). It is a monoatomic gas that has no color or smell (74). Helium finds several uses in arc welding, cryogenics, MRI scanners, gas pressurizing, and the cooling of superconducting magnets. Helium has also been historically used to reduce the incidence of decompression sickness in deep-sea diving (75).

3.3.1. Diagnostic activity

A medical imaging method called magnetic resonance imaging (MRI) is used in radiology to look into the architecture and physiology of the body in both healthy and sick conditions (76). It has been discovered that liquid helium, which boils at 4.2 K, helps produce superconducting magnets necessary for nuclear magnetic resonance and nuclear resonance imaging (77). Due to the medical profession's ability to employ magnetic resonance imaging (MRI) to diagnose complicated disorders, liquid helium usage in MRI is constantly growing (78).

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3.3.2. Vasodilatory activity

It has been found that helium increases collateral circulation in the heart (79) and strengthens the pulmonary arteries' natural vasodilatory response to breathed nitric oxide (80). It may be applied to evaluating airflow distribution and anatomical alterations in the lung parenchyma, including fibrosis and emphysema. The 2007 recommendations released by the National Heart, Lung, and Blood Institute also acknowledged heliox (a gas combination of helium and oxygen) as a critical adjuvant in the treatment of severe exacerbations of asthma (81). When children with severe asthma exacerbations were treated, pulsus paradoxus, peak flow, and dyspnea only improved with inhalational heliox therapy (82). Helium has therapeutic effects because of its faster flow rate and lower turbulent flow, which enable gases to enter the distal alveoli deeper, produce larger minute volumes, and enhance breathing (83).

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3.3.3. Neuroprotective activity

Research on neurological disorders has been done to assess the possibility of low-temperature atmospheric pressure plasma based on helium in treating conditions like Parkinson's and Alzheimer's disease, which are linked to amyloid fibrils (84, 85). Amyloid fibrils fragment into smaller units when exposed to low-temperature atmospheric pressure plasma in vitro (86). The neuroprotective properties of helium probably include many vital processes. It prevents neuronal death by inhibiting apoptosis by stabilizing mitochondrial function and decreasing caspase activity (87). By lowering pro-inflammatory cytokines and microglia activation, helium may also have anti-inflammatory effects (88). By increasing antioxidant defenses and reducing reactive oxygen species, it also aids in the reduction of oxidative stress (89, 90). To avoid excitotoxicity, helium may potentially modify ion channels and neurotransmitter systems (91, 92). It may also promote

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hypoxia tolerance, which will enable neurons to endure low oxygen levels following brain damage (93).

3.3.4. Anticancer activity

There are other effects of atmospheric pressure helium plasma jets on live cells (94, 95). Plasma interactions with several cancer cell types cause cell death, which may be related to the generation of reactive oxygen species (ROS) (96-100). Helium plasma at atmospheric pressure has been used recently to treat human lung cancer cells *in vitro* (94). It has shown promise in treating cancer cells, blood coagulation, sterilization, and teeth whitening (101-103).

Helium-based non-thermal atmospheric plasma jets have been investigated in depth in several cancer types, and *in vitro*, antitumor effects have been noted on carcinogenic cell lines associated with the skin (melanoma), brain (glioblastoma), colon, liver, lungs, breast, cervix, bladder, oral and ovarian carcinoma, and leukemia (86, 104). The anticancer activity of helium, particularly in helium ion therapy, works primarily by inducing double-strand breaks, which are hard for cancer cells to heal (105, 106). Helium possesses anticancer qualities. Helium ions also offer high precision, delivering concentrated energy to tumors while sparing healthy tissue due to their well-defined Bragg peak (107, 108). Helium ions are effective in hypoxic environments, unlike standard therapy, where cancer cells are often more resistant (109, 110). They may cause apoptosis and interrupt the cancer cell cycle (111). They may also increase immunogenic responses by promoting immunogenic cell death, fortifying the body's defenses against cancer (112).

3.4. Sodium

The word "soda," which appears in several sodium compounds like washing soda, sodium bicarbonate, and sodium hydroxide, is where the word "sodium" originates (113). The Latin name for the element, natrium, is where the sign "Na" originates. In the crust of the Earth, it ranks as the fourth most plentiful element (114). The human body needs a tiny quantity of sodium to transmit nerve impulses, contract and relax muscles, and maintain the ideal balance of water and minerals (115). It is estimated that 500 mg of sodium every day is required for these essential processes (116).

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3.4.1. Electrolyte regulation

The main solute preserving water in the extracellular compartment is sodium. Total body sodium is a prerequisite for total body water and extracellular volume. Thus, maintaining sodium balance is essential for controlling volume (117). Changes in the sodium balance cause variations in plasma volume, detected mainly by circulatory system changes (118). The most common form of IV fluid for both replacement and maintenance has historically been normal saline (119).

3.4.2. Blood pressure regulation

Blood pressure management requires the careful maintenance of salt and fluid balance, and changes to this equilibrium can result in hypertension (119). Since sodium is the primary cation in extracellular fluid, any alteration in sodium excretion through the urine would increase the amount of intravascular fluid, raising blood pressure and possibly causing hypertension (120).

3.4.3. Sodium muscularity activity

Sodium makes it easier for calcium ions to enter muscle fibers, which releases ATP, the body's energy storage (121). Due to the depolarizing effect of the muscle membrane brought on by sodium ions, the sarcoplasmic reticulum releases calcium ions, which in turn assists in triggering muscle contraction. These calcium ions use ATP to power the muscles (122) after binding to the proteins involved in muscular contraction. Proper muscle activity and electrical impulse transmission depend on the sodium and potassium ion balance (123). Moreover, magnesium is necessary for muscular contraction, and sodium promotes the dephosphorylation of ATP and ADP in the presence of magnesium (124). Consequently, sodium is an essential element for preserving optimal health, especially during the contraction of muscles (125).

3.5. Potassium

"Potash" is the root word for potassium. For a very long time, potassium carbonate and potassium hydroxide have been combined to create potash (126). In earlier times, ashes in pots were used to make potash. Potassium is a soft, silvery metal that tarnishes quickly in the air and interacts strongly with water (127).

3.5.1. Electrolyte balance

Potassium is essential for maintaining the body's electrolyte and fluid balance (128). Its participation in several physiological processes contributes to maintaining appropriate electrolyte concentrations, fluid distribution, and cellular function (129). Intake can be reduced to total loss,

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often due to famine. The kidneys filter potassium, and the amount expelled in urine is controlled to preserve equilibrium (130). Studies have also looked at electrolyte imbalance changes that occur with mental illnesses; cyclic mood disorders, such manic-depressive illness (131).

3.5.2. Acid-Base balance

In conjunction with sodium, potassium controls the body's and tissue's acid-base and water balance (132). It acts as a buffer to balance out access bases or acids, assisting in stabilizing the organism's internal environment (133). Potassium affects the body's hydrogen ions concentration, which is essential for maintaining acid-base equilibrium (134). High potassium levels induce hydrogen ions inside cells, raising pH (alkalosis) and reducing extracellular hydrogen. On the other hand, low potassium causes cells to release hydrogen ions, which increases extracellular hydrogen and lowers pH (acidosis) (135). The kidneys regulate Potassium excretion, which also influences hydrogen ion secretion and bicarbonate reabsorption (134). The respiratory system also contributes to regulating CO_2 levels, which indirectly affects potassium and acid-base balances (136). The preservation of general homeostasis depends on this interaction. Normal metabolic and cellular functions depend on appropriate potassium levels (137).

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Ions are necessary to sustain the acid-base balance, and pH levels are directly influenced by hydrogen ions (H^+) (138). While potassium ions (K^+) assist in moving hydrogen ions across cell membranes, affecting the overall acid-base state, bicarbonate ions (HCO_3^-) function as an essential buffer. In this complex equilibrium, other ions, such as sodium, chloride, magnesium, and calcium, also play supporting roles (136).

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3.5.3. Cardioprotective activity

In the heart, potassium is essential for the passage of electrical impulses (139). Maintaining a normokalemia condition is crucial for the prevention of potentially significant consequences and for the preservation of cardiovascular health, particularly in individuals who are at risk for cardiovascular disease (140). Serum K^+ values kept between 4.0 and 5.0 mmol/L seem safe and likely to offer stability in various cardiovascular processes (141). Increased consumption of potassium-rich foods is linked to a decreased incidence of stroke and may also lessen the risk of congenital cardiac conditions and overall cardiovascular disease (142). These

findings corroborate suggestions to increase the intake of foods high in potassium to prevent vascular disorders (143).

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3.6. Rubidium

An alkali metal in Group 1 of the Periodic Table is rubidium. Its physical and chemical characteristics often fall between those of cerium and potassium (144). Rubidium is not the major metallic element in any mineral. Rubidolite and pollucite are the minerals that contain rubidium (145). In general, rubidium is classified as having a low level of toxicity. There are health dangers related to chemicals called rubidium (146). Rubidium is mainly used in research. Pharmaceuticals and medical procedures both employ rubidium isotopes (147).

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3.6.1. Cardiac imaging

In particular, coronary artery disease is one cardiovascular illness for which rubidium is used in diagnosis and treatment (148). A radioactive isotope of rubidium called rubidium-82 is utilized as a positron-emitting radiotracer in cardiac imaging. Rubidium-82 PET (Positron Emission Tomography) imaging is the name of this application (149). It is frequently used to evaluate blood flow to the heart muscle in myocardial perfusion imaging. When assessing the myocardial perfusion of individuals with known or suspected coronary artery disease, rubidium-82 PET imaging is beneficial (150).

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3.6.2. Neurological research

Rubidium's ability to mirror the behavior of potassium has made it a helpful ion in neurological studies (151). Researchers have utilized rubidium influx as a measure of neurotransmitter release because rubidium ions may enter neuron terminals and imitate the actions of potassium (152). Rubidium has been combined with electrophysiological methods, such as patch-clamp recordings, to investigate the electrical characteristics of neurons (153). Evaluation of rubidium's effects on membrane potential, action potentials, and other electrophysiological parameters may be part of these investigations (154). A few studies have looked at rubidium's possible neuroprotective benefits (155). Changes in brain rubidium levels can strongly predict Alzheimer's disease. Rubidium 82/86 PET imaging may be able to detect Alzheimer's disease in its early stages (151). It has been claimed that lithium and rubidium have neuroprotective effects on disorders of the central nervous system, such as mania and depression (156).

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3.6.3. Diagnostic marker for brain tumor

Positron emission tomography (PET) has made considerable use of rubidium-82 as a diagnostic marker for brain tumors; greater absorption of the tracer indicates a breakdown in the integrity of the blood-brain barrier (BBB) (157).

3.7. Cesium

In 1860, Gustav Kirchoff and Robert Bunsen discovered cesium (158). The soft, alkaline metallic element cesium has a silver-white color and atomic number 55. As the isotope 133Cs, it is the rarest naturally occurring alkali metal. With a cesium oxide content ranging from 5% to 32%, pollucite is the most widely used commercial cesium source (159). Cesium in radioactive forms (134Cs and 137Cs) is also present in the environment. When cesium was radioactive and had the potential for radiation therapy and carcinogenesis, it first attracted interest (160). When cesium metal comes into touch with flesh, it may burn people severely (161). Cesium has limited practical uses in neurology because of its possible toxicity. Serious health concerns, including as cardiovascular, gastrointestinal, and neurological disorders, can result from cesium poisoning (162). As a result, using cesium therapeutically is quite rare in traditional medicine and calls for great caution (163).

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3.7.1. Anticancer activity

It has been proposed that cesium chloride as a cancer treatment, often known as "high pH therapy," will have anticancer effects by increasing intracellular pH and inducing apoptosis (164). Since the 1980s, anticancer efficaciousness for steady cesium treatment has been asserted. Studies conducted *in vivo* have demonstrated a substantial reduction in tumor volume following the treatment of oral gavage or intraperitoneal injection of calcium chloride (165). Prostate cancer has been treated using 131Cesium brachytherapy (166).

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3.8. Francium

Marguerite Perey discovered francium in 1939 (167). It is the lustrous metal in its purest form, existing at room temperature as a liquid instead of a solid. It emits a lot of radioactivity. With a maximum half-life of just 22 minutes, it is a radioactive metal that is heavy and unstable (168). The chemical characteristics of francium and cesium are comparable (169). After astatine, it is the second rarest element in the crust of the Earth. It is the most chemically reactive alkali metal since it is the most minor electronegative element among all of the elements (170). There is no known

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biological function of francium in human life. Due to its volatility and scarcity, francium has no commercial use. It is exclusively utilized for research. Its use as a potential diagnostic tool for various malignancies has also been examined, although this use has been judged unfeasible. Its only toxicity is from its radioactivity, which can harm nuclear material and cells (171).

3.9. Beryllium

Wohler made the first isolation of beryllium in 1828 (172). It is a lightweight alkaline earth metal with a steel-gray color. It is the only metal with the unusual quality of being almost X-ray transparent (173). It is harmful when breathed or applied topically, and it can cause dermatitis, acute pneumonitis, and chronic lung disease (174). Breathing problems, chest discomfort, or shortness of breath may be the initial symptoms of a severe or potentially fatal acute beryllium exposure (175). In conclusion, beryllium is not used in pharmaceutical applications because its hazardous properties outweigh any potential therapeutic benefits (176).

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3.9.1. Chronic beryllium disease (CBD)

Berylliosis, sometimes called chronic beryllium disease (CBD), is a granulomatous illness brought on by beryllium exposure (177). Granulomas, or abnormal inflammatory nodules, form in the lungs and other regions of the body as a result of a systemic illness (178). The most frequent symptoms are cough, fever, night sweats, and exhaustion, although the clinical course might vary. The beryllium lymphocyte proliferation test (BeLPT), bronchoalveolar lavage (BAL), and granulomatous inflammation on lung biopsy are the mainstays of a conclusive diagnosis of berylliosis (179).

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3.10. Magnesium

Magnesia, a location in Greece, is where magnesium compounds were initially found. In the Earth's crust, magnesium is the seventh most abundant element (180). It is an alkaline Earth metal that occurs in minerals and rocks in the natural world (181). Just 1% of the magnesium in the body is found in the blood, with the majority of the mineral being in high metabolic tissues such the muscles, brain, heart, kidneys, and liver (182). The human body uses magnesium (Mg^{2+}) for various processes, including blood pressure, neuromuscular transmission, and muscle contraction (183, 184). Furthermore, magnesium is crucial for creating nuclear materials, generating energy, active transmembrane transport for other ions, and bone growth (185). Moreover, a variety of illnesses have been linked to magnesium deficiency (186).

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3.10.1. Cardiovascular health

Magnesium is essential for preserving heart health (187). Magnesium affects vascular tone, peripheral vascular resistance, and endothelial function, and it has a significant role in the control of heart rhythm. Hypomagnesemia is associated with an increased risk of cardiac arrhythmia. Additionally, hypomagnesemia increases the risk of postcardiac surgery atrial fibrillation. Persons with congestive heart failure are more likely to have low potassium and magnesium levels in their blood (188).

3.10.2. Maintain heart rhythm

Magnesium is crucial for the adequate functioning of ion channels, such as those that regulate the heart's electrical activity. It contributes to the preservation of a regular heartbeat and aids in the stabilization of cell membranes (189). Adequate magnesium levels can support the heart's overall electrical stability and help prevent arrhythmias or irregular heartbeats (190).

3.10.3. Blood pressure regulation

Magnesium helps manage blood pressure. It facilitates blood channel dilation, which lowers peripheral resistance and increases blood flow (191).

3.10.4. Anti-inflammatory effects

Cardiovascular disorders are linked to chronic inflammation (192). Due to its anti-inflammatory qualities, magnesium may help lower inflammatory processes in the cardiovascular system and promote heart health (193, 194).

3.10.5. Preventing Coronary Artery Spasms

Coronary artery spasms are abrupt contractions of the coronary arteries that might lower cardiac blood flow. Magnesium can help avoid these spasms (195). Magnesium may help to prevent these spasms by encouraging the relaxation of smooth muscles (196).

3.10.6. Protecting Against Ischemia-Reperfusion Injury

The possible preventive benefits of magnesium against ischemia-reperfusion injury, a condition in which blood flow is momentarily obstructed and then restored, have been investigated. Magnesium's ability to reduce inflammation and oxidative stress may help protect the heart from such damage (197, 198).

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3.10.7. Laxative effect

It is well-known that magnesium and sulfate have laxative properties (198). Patients commonly treat constipation using over-the-counter medications, such as magnesium hydroxide (Milk of Magnesia) or magnesium citrate (199-201). Magnesium acts as a laxative through two primary mechanisms. Initially, it pulls water into the intestines by osmosis, which makes the feces softer and more moisturized, facilitating passage. Second, magnesium increases the contraction of intestinal muscles(peristalsis), enabling faster feces passage through the digestive system (202). The laxative effect is caused by this combination of increased water content and improved intestinal movement (203).

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3.10.8. Migraine prevention

Magnesium is a cheap, safe, and well-tolerated migraine preventive alternative, according to the NCBI (204). Acute headaches, such as tension-type headaches, migraines, and cluster headaches, may also benefit from its use. One kind of magnesium that is frequently used to stop migraines is magnesium oxide (205, 206). One kind of magnesium that is frequently used to stop migraines is magnesium oxide (205, 206). Magnesium has many mechanisms of action in migraine prevention (206, 207). Neurotransmitters like serotonin, which are important in migraines, are regulated by it (208).

Additionally, magnesium blocks calcium channels, lessening excessive neural excitability and stopping the release of chemicals that cause pain (209). Furthermore, relaxing blood vessels enhances vascular tone and helps avoid the vasoconstriction and dilation linked to migraines (210). Adding to magnesium's preventative benefits is its capacity to reduce oxidative stress and inflammation (211). Magnesium deficiency is associated with a higher chance of migraines, underscoring the mineral's significance for preserving vascular and neurological function (212).

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3.10.9. Pre-eclampsia prevention

A lot of people use magnesium sulfate to avoid eclamptic seizures (213). In preeclamptic women, $MgSO_4$ is more effective than phenytoin, nimodipine, diazepam, and placebo for eclamptic seizure prevention (214). Additionally, magnesium sulfate may function as a central anticonvulsant or preserve the blood-brain barrier while preventing the development of cerebral edema (215-218)

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3.10.10. Bone health

Given its importance to bone health, magnesium may be a useful nutrient in the fight against osteoporosis and bone loss (219, 220). A magnesium deficit may impact bone by lowering bone mineral density, boosting osteoclasts, and decreasing osteoblasts that interfere with vitamin D. This causes oxidative stress and inflammation, ultimately leading to bone loss (221).

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3.11. Calcium

In London in 1808, Cornish chemist Sir Humphry Davy discovered calcium. Its name comes from the Latin word "calx," which means "lime" (limestone is a calcium ore) (222). Calcium is a soft element of the alkali earth metal family. It is the most prevalent of all the metallic components that make up the human body (223). There is no toxicity to calcium. It is a necessary mineral for the growth of strong bones and teeth, as the primary component of bones is calcium phosphate (224-226). Calcium shortage can lead to osteoporosis, osteopenia, hypocalcemia, and other illnesses (227). Although calcium is not a medicine in and of itself, supplements and products containing calcium are utilized for various pharmacological purposes (228). For adults, the recommended calcium intake (RDI) is 1,000 mg daily (229).

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3.11.1. Bone health

In addition to being essential for maintaining healthy bones, calcium is frequently used to treat and prevent osteoporosis and osteopenia (230). To increase bone density and lower the risk of fractures, doctors commonly prescribe calcium supplements along with vitamin D, particularly for people deficient in these nutrients or at risk for bone-related illnesses (231, 232). Early adult peak bone mass is determined by the amount of calcium an individual consumes, which also impacts skeletal calcium retention during growth (233). At a later age, calcium also helps to prevent osteoporotic fractures and bone loss (234).

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3.11.2. Antacids

An ionic substance called calcium carbonate is used as an antacid or calcium supplement to treat the symptoms of acid reflux, heartburn, and sour stomach. It is a simple substance that balances hydrochloric acid's acidic effects in stomach secretions (235) .

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3.11.3. Cardiovascular health

A family of drugs known as calcium channel blockers is used to treat a number of cardiovascular diseases, such as hypertension (high blood pressure) and certain arrhythmias (236). These drugs function by obstructing the calcium channels in the heart and blood vessels, which causes the smooth muscle to relax and the blood vessels to dilate (237).

3.12. Strontium

First found in a mine in 1790, strontium was separated in 1808. Strontium is an alkaline earth metal, a delicate silver-white yellowish metallic element chemically reactive (238). This silvery metal is a non-radioactive element that occurs naturally. Strontium possesses physical and chemical characteristics comparable to its two vertical neighbors in the periodic table, calcium and barium (239). The bones contain 99 percent of all the strontium in the human body. Its pharmacological uses are mostly related to the treatment of osteoporosis (240, 241). Because of its radioisotopes, strontium has become more critical in nuclear medicine, primarily for the soothing and pain-relieving therapy of bone metastases (242).

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3.12.1. Osteoporosis treatment

The most significant cation in bones is strontium, which can fight osteoporosis by promoting the proliferation of osteoblast cells and preventing bone reabsorption (241). In osteoporotic individuals, strontium ranelate lowers the fracture rate and raises bone calcium (243). In the bone structure, strontium-coated halloysite nanotubes (SrHNTs) strengthened the bone and stimulated osteoblasts to produce new bone (244). It can load drugs, lower bone reabsorption, and exhibit antibacterial action (245).

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3.12.2. Dentistry

Strontium can strengthen bones and shield teeth against decay (246). It has also been discovered that strontium-substituted hydroxyapatite (SrHAp) nanoparticles enhance tooth remineralization by raising the ALP activity, which is linked to the cloning process in hard tissues (247, 248).

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3.12.3. Anticancer activity

Strontium nanoparticles, or SrNPs, find applications in chemosensory medicine, bioimaging, and cancer treatment (249). Chemosensing, medication delivery, cancer treatments, and biomedical imaging all employ strontium-suspended vesicles (250).

2.12.4. Antimicrobial activity

Gram-positive and gram-negative bacteria were both susceptible to the antibacterial properties of strontium cerium oxide (SrO-CeO_2) nanoparticles (251, 252). Gram-negative bacteria are more likely to attach themselves to SrO-CeO_2-combined NPs (253). Strontium oxide nanoparticles (SrONPs) displayed excellent antibacterial activity against gram-negative bacteria such as *Proteus vulgaris*, *Pseudomonas aeruginosa*, *Morganella morganii*, and *Klebsiella pneumonia* than that of gram-positive bacteria (254, 255). Strontium demonstrates antimicrobial activity via several pathways (256). Bacterial cell membranes may be damaged by it, increasing permeability and resulting in cell death.

Additionally, strontium disrupts bacterial metabolism by influencing enzymatic functions essential to bacterial proliferation. It also prevents the development of biofilms, which bacteria utilize as a defense against immune system assaults and antibiotics (257). Strontium can attach to bacterial proteins or DNA, impairing transcription and replication (258). Its benefits are notably advantageous for bone-related infections and wound healing. Strontium is a helpful antibacterial agent because of its capacity to weaken bacterial defenses. Its action improves overall infection management by lowering bacterial resistance (259).

3.12.5. Analgesic activity

Due to its radioisotopes, strontium has become more critical in nuclear medicine, primarily for the comforting and pain-relieving treatment of bone metastases (260, 261). Many pathways mediate the analgesic activity of strontium. By blocking calcium channels, it lowers neurons' excitability and pain transmission. Moreover, strontium possesses anti-inflammatory qualities that reduce pro-inflammatory cytokines connected to pain (262). By boosting bone growth and decreasing resorption, it encourages bone remodeling, which lessens discomfort in diseases like osteoporosis (263). Strontium may also reduce pain perception by modulating pain receptors. It works well for illnesses like osteoarthritis and bone-related pain because of these combined activities (264).

3.13. Barium

One of the alkaline-earth metals in group 2 (IIa) of the periodic table is barium (Ba) (261). It is a prevalent element in the crust of the Earth, occurring naturally in one oxidation state (+II) and at a concentration more significant than that of most other trace elements (265). The most prevalent minerals of Barium are hollandite and barite, typically related to potassium in geochemical

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processes (266). Barium is mainly known for its poisonous qualities, and it is not thought to have any substantial therapeutic effect. When consumed or breathed, barium compounds can cause toxicity by interfering with cellular functions, mainly by inhibiting potassium channels (267).

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3.13.1. Anti-ulcer activity

Barium oxide (BaBG) is a novel bioactive glass that may be used as an anti-ulcer agent (268).In several ulcer models, including ethanol, aspirin, gastric ulcers caused by pyloric ligation, duodenal ulcers caused by cysteamine, and ulcers that heal when exposed to acetic acid, BaBG was found to minimize ulcerative damage greatly (269). BaBG has been shown to neutralize stomach acid, promote cell proliferation, and provide a physical protection barrier over the gastro-duodenal epithelial cell (270). It also increased the pH of the stomach, exhibiting antacid-like effects (268) .

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3.13.2. Diagnostic activity

Since barium sulfate is mainly employed as a contrast agent in medical imaging rather than for therapeutic purposes, it is not usually recognized for its pharmacological properties in the conventional sense (271). Most frequently, barium sulfate is used as a contrast agent in treatments like barium enema and swallow (272). The esophagus, stomach, and intestines are highlighted in these imaging investigations, which aid in visualizing the gastrointestinal system. Barium sulfate is appropriate for this use since it is insoluble and inert (272). It covers the lining of the gastrointestinal tract during imaging examinations. The organs and tissues under examination are more visible because to this covering (273, 274).

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3.14. Radium

The heaviest of the Group 2 (IIa) alkaline-earth metals in the periodic table is radium (chemical symbol Ra) (275). The discovery was made by Marie and Pierre Curie in 1898. It is created when uranium decays, releasing gamma, beta, and alpha ionizing radiation (276). An aqueous solution produces colorless radium cation, which is very basic and does not form complexes. As a result, the majority of radium compounds are basic ionic compounds (277). It exists in trace amounts in rocks, soil, and water in the natural environment. Radon is a radioactive gas created when some of the atoms in radium decay and release radiation (278-280). One type of anticancer medication is radon. In terms of radium isotopes, Ra-226 and Ra-228 are the most prevalent (281). The chemistry

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of radium is comparable to barium, which is widely employed as a substitute due to the high radiation of radium (282).

3.14.1. Anti-cancer activity

The first and only alpha-emitting radiopharmaceutical to be approved for clinical use by the FDA and EMEA for treating metastases linked to metastatic castration-resistant prostate cancer (mCRPC) is [Ra-223] radium chloride (Xofigo®; previously alpharadin) (283-285). Six intravenous doses totaling 50 kBq kg^{-1} and [Ra-223] Cl_2 are given, with a four-week interval between each administration. After entering the body, [Ra^{2+}-223] will work as a Ca^{2+} imitator and form complexes with the mineral hydroxyapatite at locations where the bone is actively growing, which happens in metastatic bone tissue at a faster pace. Through a multimodal method, Ra-223 kills tumor cells, osteoblasts, and osteoclasts, the effector cells of pathological bone metabolism (286). It may also stimulate local immunological responses against tumors (287).

3.14.2. Ankylosing spondylitis treatment

Radium chloride was first used to treat ankylosing spondylitis in 1948 (288). A course of ten weekly injections, totaling roughly 50 MBq, was administered for most patients. Positive clinical outcomes were documented for ankylosing spondylitis patients, indicating a sustained effect and decreased requirement for analgesic and anti-inflammatory medications (289).

4. Conclusion

In conclusion, the s-block elements, including alkali and alkaline earth metals, exhibit diverse and significant roles in health, disease, and medical research. From neurological research to anticancer activity, these elements have shown potential therapeutic applications, such as lithium's neuroprotective effects and cesium's investigation for anti-cancer properties. These elements' pharmacological potential also extends to helium's applications in human life and medical treatments. This comprehensive overview highlights the multifaceted potential of s-block elements in medicine and research. These findings would motivate us to conduct additional analysis and testing to show the effectiveness of s-block elements as prospective medical options.

5. Future Aspects

Future research in pharmacology and medicine may increasingly use alkali and alkaline earth metals (S-block elements). Enhancing therapeutic techniques, such as drug delivery systems, tissue

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regeneration, and treating metabolic and cardiovascular diseases, maybe the primary focus of these applications. Technological developments in bioimaging, biocompatibility, and nanotechnologies offer the potential to improve their medical uses while addressing toxicity issues. Furthermore, collaborative research and sustainable sourcing are crucial for the future development of environmentally friendly and more effective medicinal advancements using these metals, fostering collaboration across medicine, pharmacology, and materials science.

Acknowledgments

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